V5 Validation of AIRS Land Surface Temperature and IR Emissivity Products

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Topics: AIRS Land Surface LST & LSE

1. AIRS data over Snow and Ice Scenes

   Paper submitted to TGARS special issue as part of the ITWG Land Surface Workshop (June 2006). Preprint available.

2. MEASURES Proposal Advertisement (Simon Hook, PI)

3. AIRS PGE Version 5 Improvements
   - Case study: Egypt
   - MODIS/AIRS comparison: Africa & Global
   - V5 preliminary conclusions

A Proposed Methodology for the Determination of Surface Temperature and Effective Infrared Emissivity for Advanced Infrared Sounder Fields of View at High Latitudes

Robert O. Knuteson, Szu Chia Moeller, David C. Tobin, and Henry E. Revercomb

***Abstract*— A methodology to retrieve the effective land surface infrared properties of snow surfaces is presented that takes advantage of the high spectral resolution observations of a new generation of advanced infrared sounders aboard polar orbiting weather satellites. Application of the method described here is intended for the high latitude polar regions, e.g. Siberia, Alaska, Canada, Greenland, and Antarctica. The method is for the identification of uniform fields of view of the sounder using collocated imager infrared data and the estimation of corresponding effective surface infrared emission across the thermal infrared using the known spectral dependence of snow and ice emissivity. An example over the Greenland ice sheet is presented. The correct interpretation of the surface emission is an important component of making high latitude data from advanced infrared sounders useable in Numerical Weather Prediction data assimilation.**

***Index Terms*—Remote Sensing, Satellites, Snow, Weather Forecasting**

I. Introduction

A new generation of infrared sounders for future weather satellites is being developed in the United States and Europe for obtaining improved profiles of atmospheric temperature, water vapor, and trace gas concentrations. The NASA Atmospheric Infrared Sounder (AIRS) on the EOS Aqua platform was the first of a series of high spectral resolution sensors that includes the operational Infrared Atmospheric Sounding Interferometer (IASI) on Europe's METOP platforms and the Cross-track Infrared Sounder (CrIS) on the U.S. National Polar Orbiting Environmental Satellite System platforms [1]-[3]. A characteristic of these advanced infrared sounders is the use of spectrometers with nearly continuous coverage across the thermal emission spectrum with resolving powers of 1000 or greater. These high spectral resolution IR sounders have the advantage of being able to resolve individual absorption lines of water vapor and carbon dioxide and thereby provide a number of transparent micro-windows that require a smaller atmospheric correction than broad-band instruments. One of the goals for these new sensors is to provide atmospheric sounding data over land and frozen ocean where satellite soundings have yet to be fully utilized. This paper proposes a methodology for the proper use and interpretation of high spectral resolution infrared sounder observations over snow and ice that is suitable for numerical weather prediction (NWP) direct assimilation of radiances.

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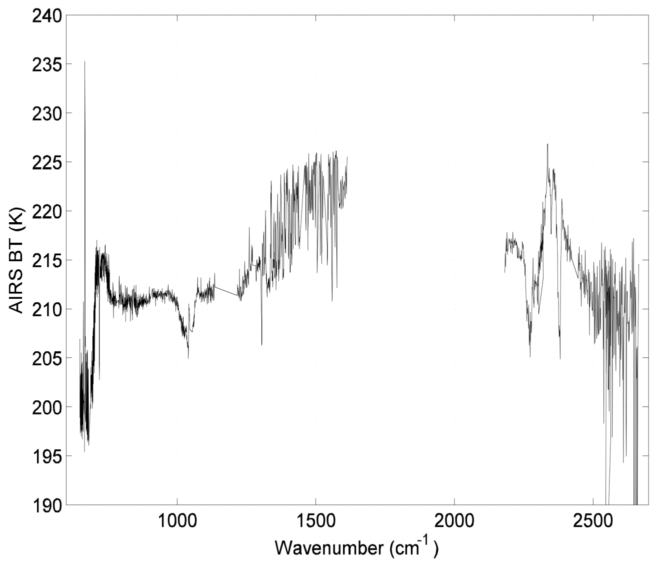
II. Infrared Radiative Transfer Theory

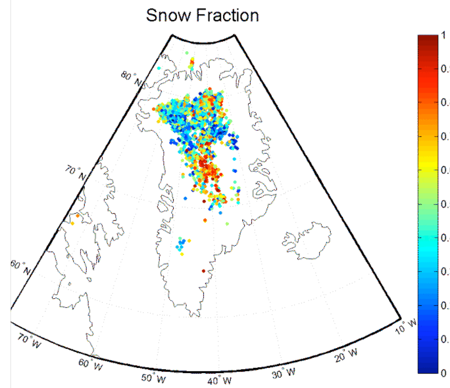
This paper will follow the notation of [4] for the cloud-free radiative transfer equation, neglecting solar radiation and scattering effects, of a downlooking infrared sensor viewing a homogeneous surface

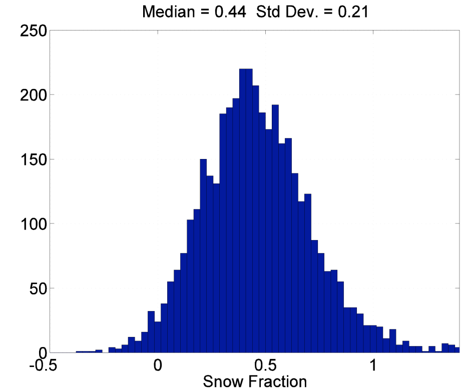
$$I_\nu = \int_0^Z B_\nu[T(z)]\frac{\partial \tau_\nu(z,Z)}{\partial z}dz + \varepsilon_\nu \cdot B_\nu(T_S)\cdot \tau_\nu(0,Z) + (1-\varepsilon_\nu)\cdot \tau_\nu(0,Z)\int_\infty^0 B_\nu[T(z)]\frac{\partial \tau_\nu(z,Z)}{\partial z}dz, \quad (1)$$

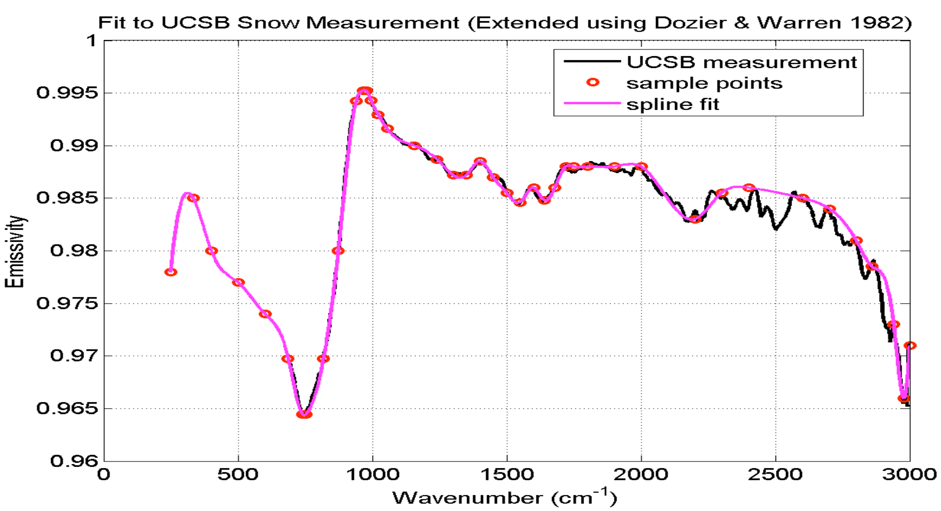
where I_ν, ε_ν, B_ν, T_S, $\tau_\nu(z_1,z_2)$, Z, and $T(z)$ are observed spectral radiance, spectral emissivity, Planck function, the surface skin temperature, spectral transmittance from altitude z1 to z2, sensor altitude, and air temperature at altitude z, respectively. The first term of (1) is the emission from the atmosphere above the surface, the second term is the direct emission from the surface that reaches the sensor, and the third term is the IR downwelling atmospheric flux reflected at the surface and transmitted to the sensor under the approximation of a lambertian surface.

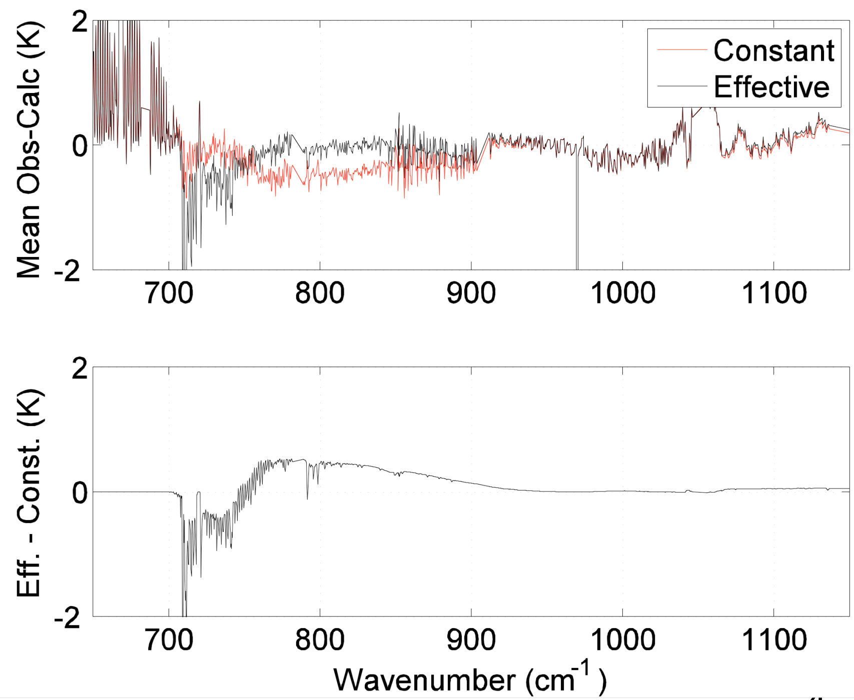
AIRS Data Over Greenland: January 2005











A Unified Land Surface Emissivity Product for Earth Science Research

By

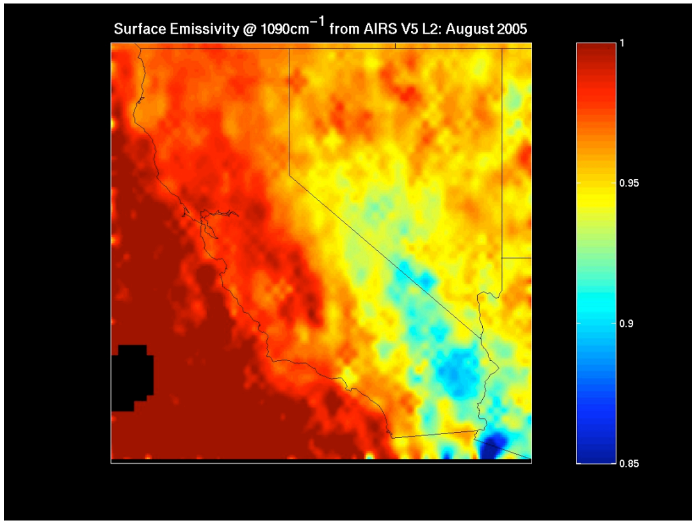
Simon J. Hook (PI – JPL)
Robert E. Dickinson (Co-I – Georgia Tech)
Dorothy K. Hall (Co-I – GSFC)
Robert O. Knuteson (Co-I - UW-Madison)
Jeffrey L. Privette (Co-I – NOAA)

Moustafa Chahine (Collaborator-JPL)
John Le Marshall (Collaborator-BoM)
Ana C. T. Pinheiro (Collaborator – NOAA)
Fuzhong Weng (Collaborator – JCSDA)

Response to NNH06ZDA001N (ROSES A-22)

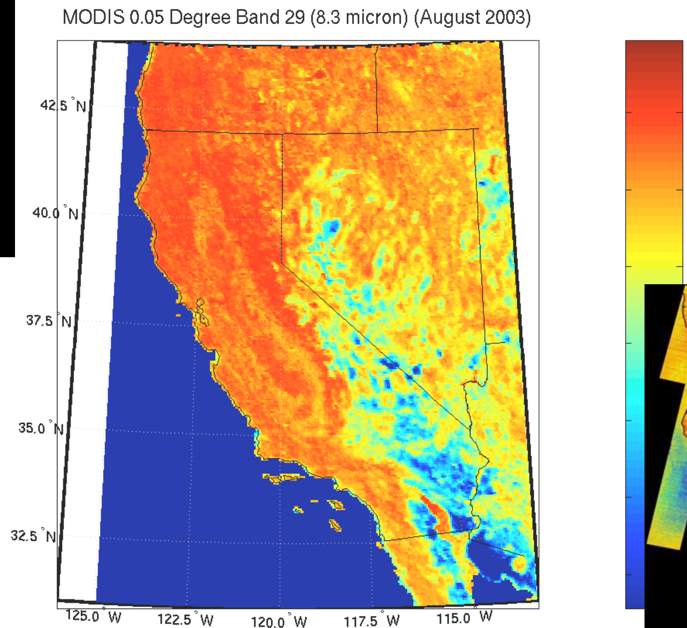
NASA EOS Land Products

AIRS V5 (45 km)

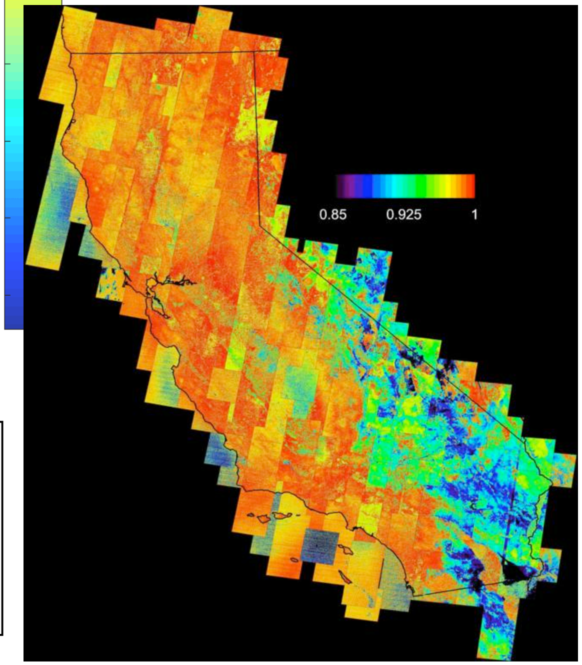


8.5 and 9 μm emissivity is low when bare soil (quartz) is exposed.

MODIS (5 km)



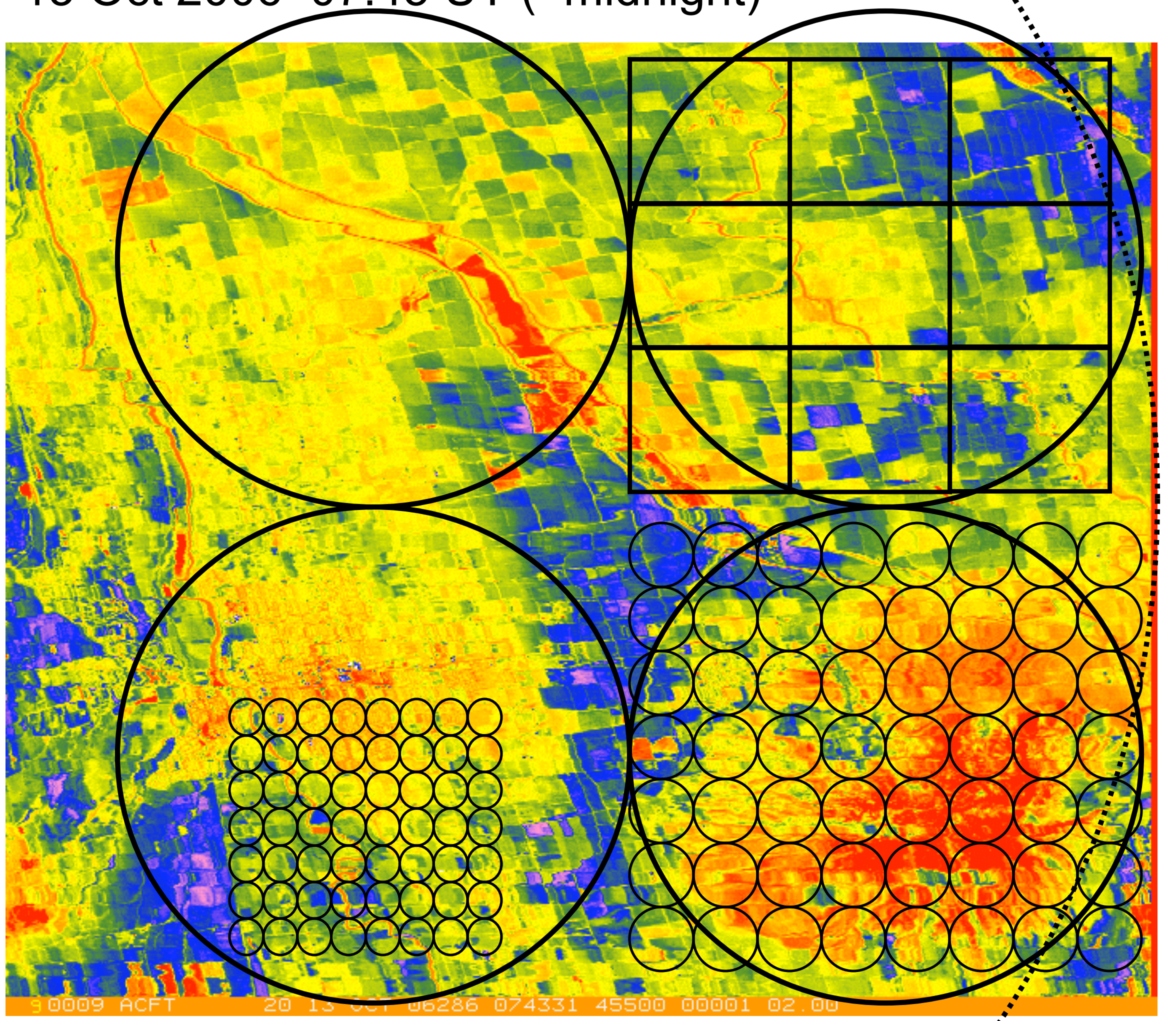
ASTER (0.090 km)



Goal is to create a Unified Product at several scales that combines data taking advantage of the strengths and weaknesses of each product.

Sacramento Valley

13 Oct 2006 07:45 UT (~midnight)



ER-2 Flight 13 October 2006

Sensor FOV Size

(nominal at nadir)

AMSU (~45 km)
(AIRS Team Product)

AIRS (~16 km)
(UW Single FOV)

MOD11C (~5 km)
(MODIS LST/LSE)

S-HIS (~2 km)
(UW LST/LSE)

MODIS (~1 km)
(a priori needed)

ASTER (~90m) → MODIS Airborne Simulator (~ 50 m) - Full Resolution

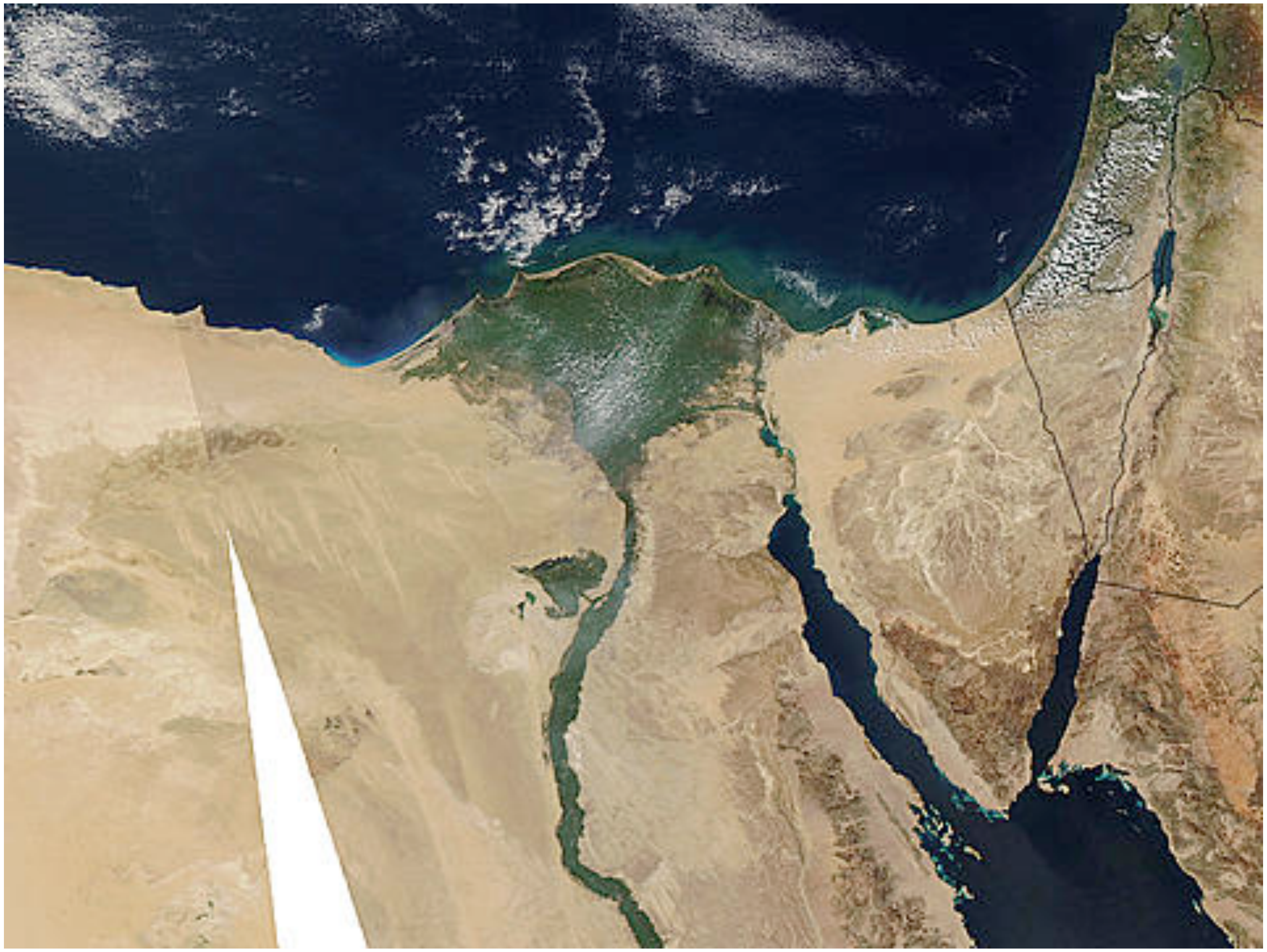
AIRS V5 Land Surface: A Brief History Time

- In the beginning, water covered the Earth (Ver. 3).
- Waters began to recede from the land (Ver. 4)
- Dry land is exposed for the first time (Ver. 5)

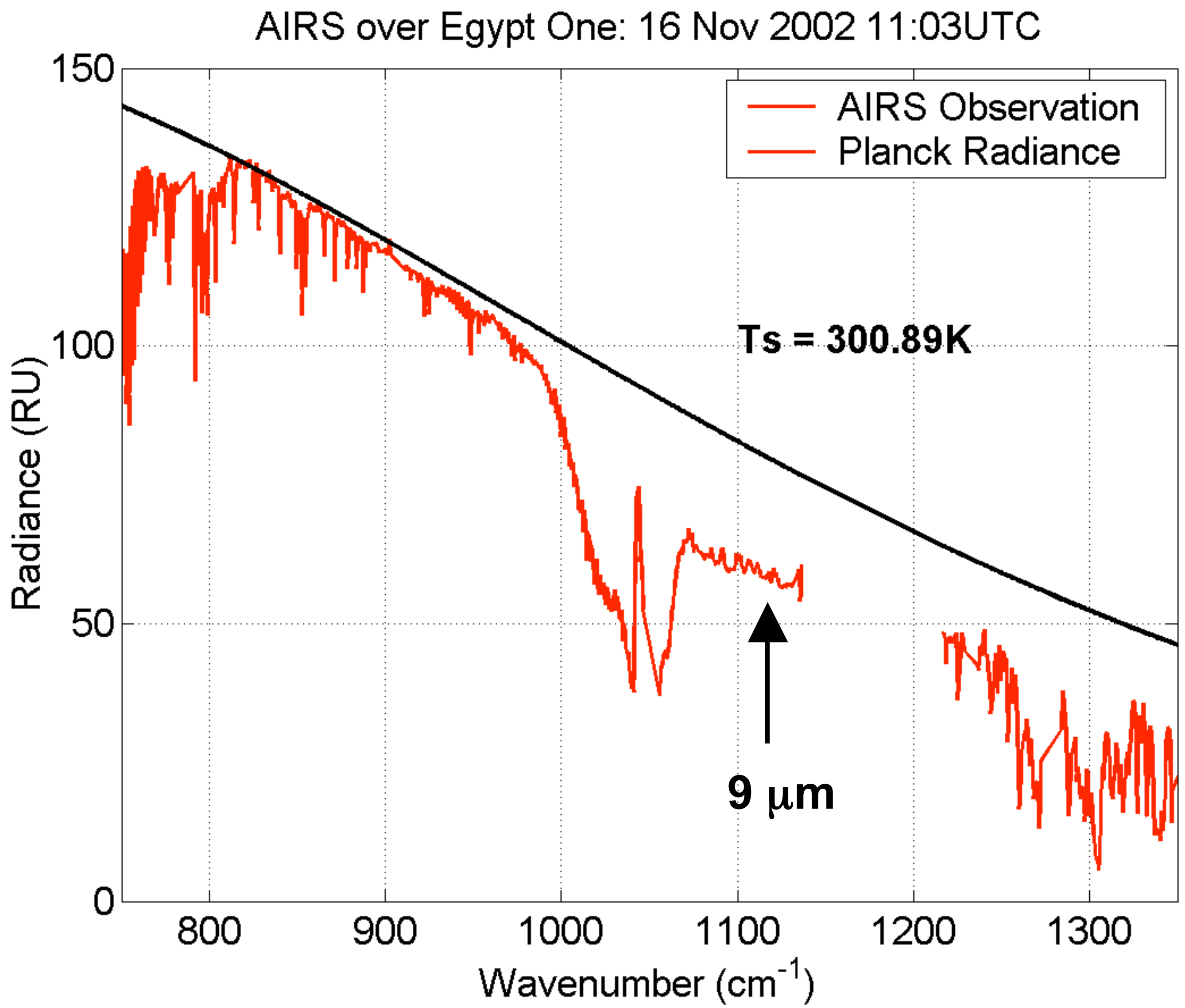
But how well is Version 5 working?

- I first presented results to the science team in 2004 regarding the land emissivity signal that was present in the AIRS data.
- In the past three years I have focused on creating validation data streams using multiple methods.
- What follows is a very preliminary look at results available from the PGE only for the past few weeks.

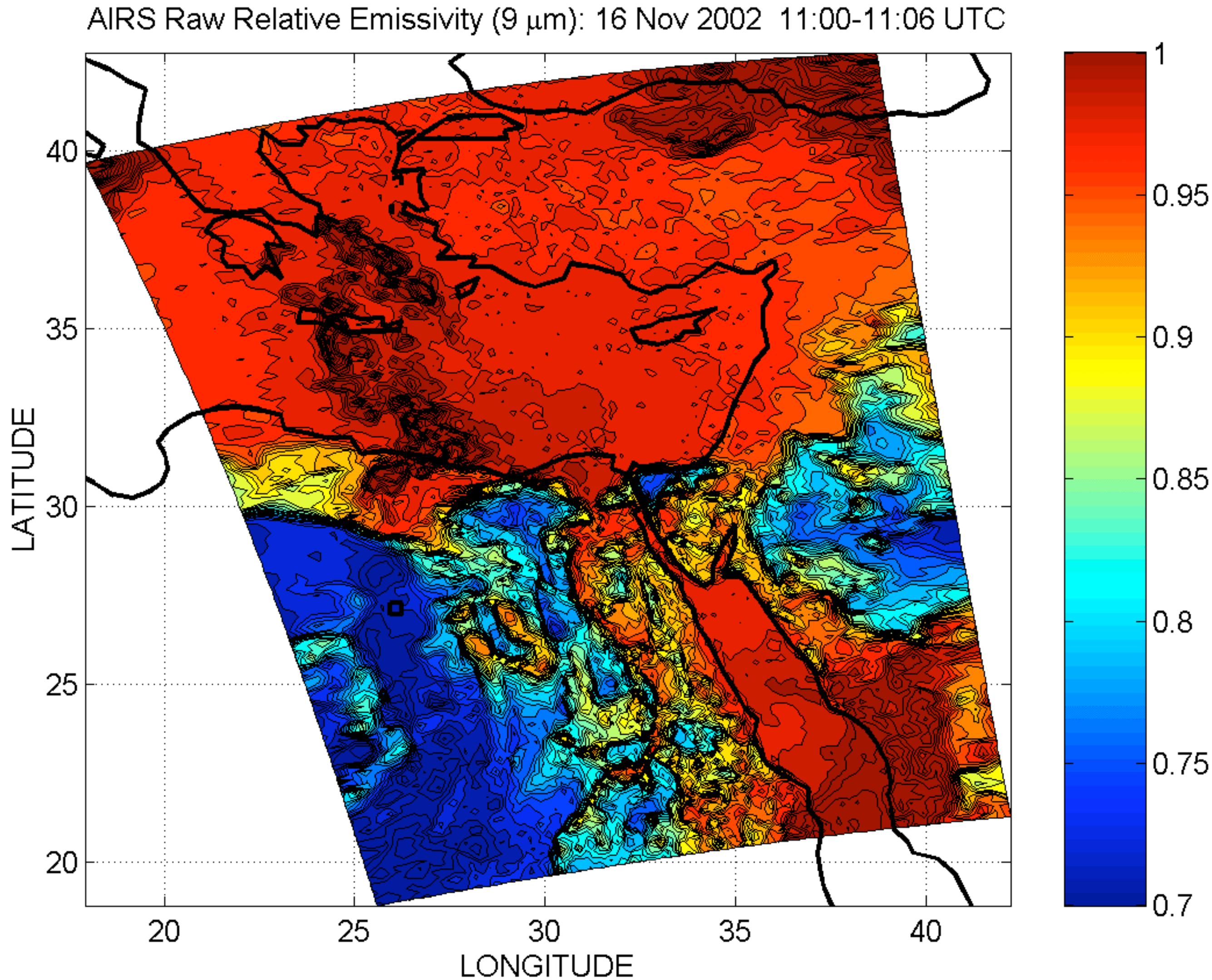
Case Study : Egypt



Case Study: Egypt

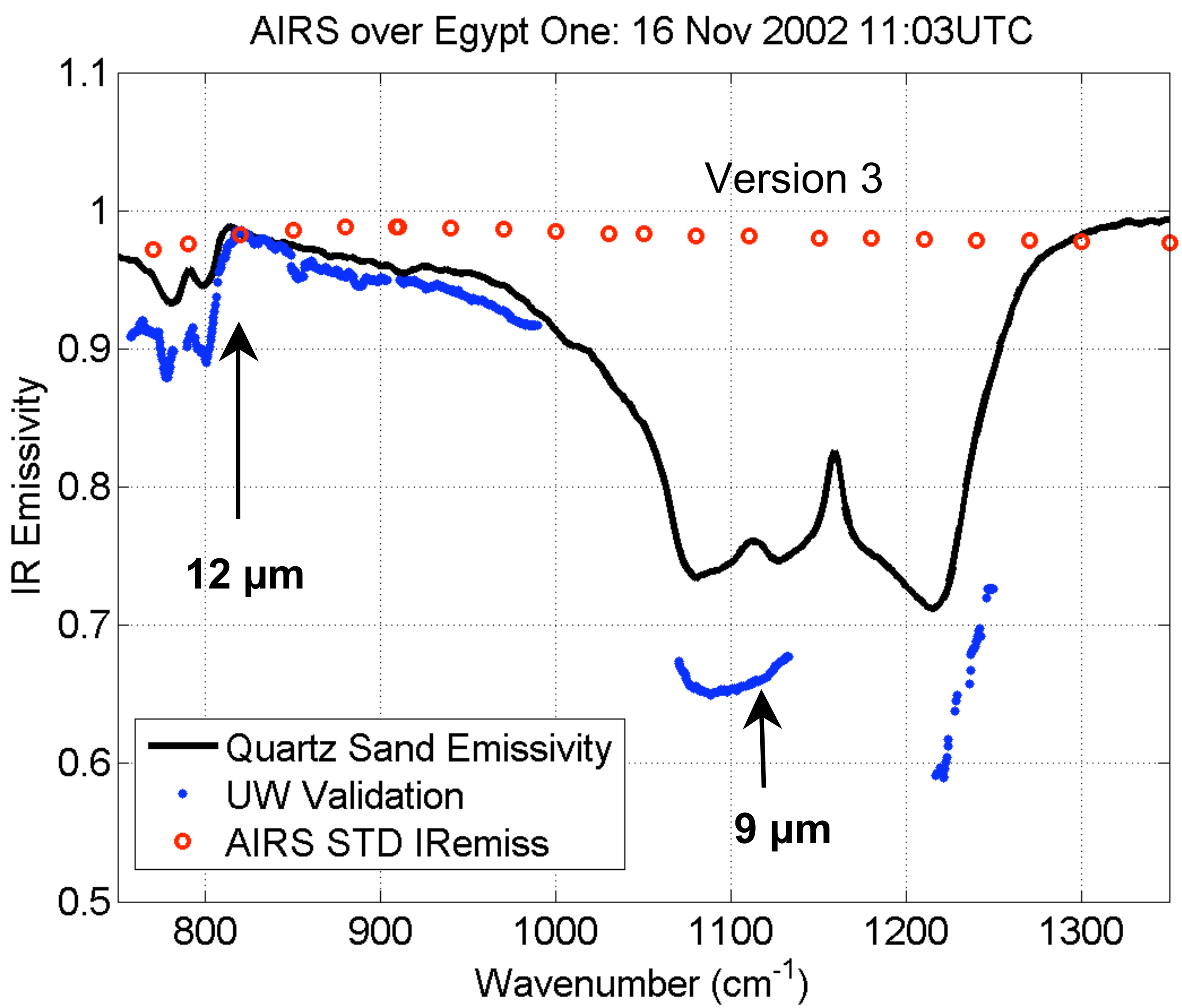


UW “Truth” Provided Three Years Ago



Relative Emissivity at 9 microns

Status Three Years Ago: Version 3



Where are we now?

Version 4.0.9 --- 5 Years available from Goddard

Version 5.0.9 --- Test data from JPL Team Facility

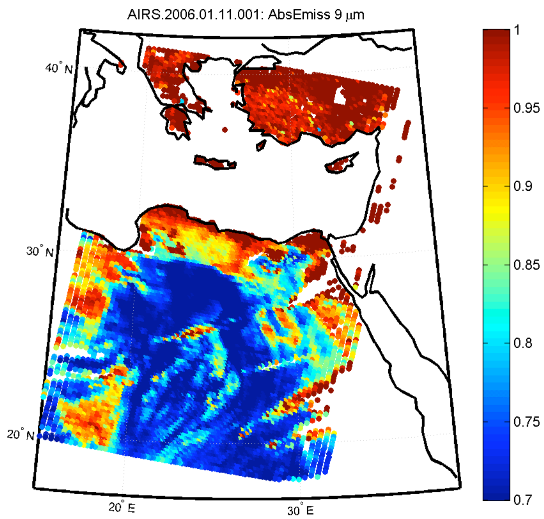
Evaluating cases from 2006 to provide Sahara land surface Emissivity background in support of UMBC dust study.

UW LSE Spectral Variance

AIRS STD Version 4.0.9

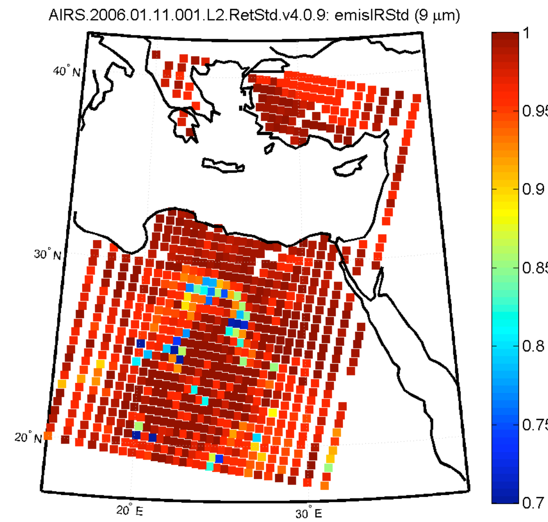
V4

9 µm



1.0

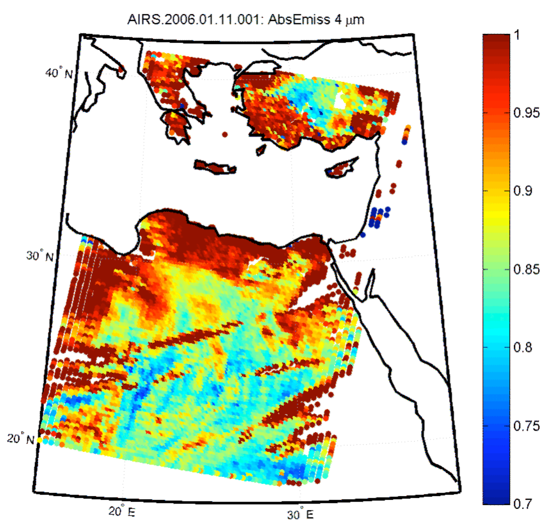
0.7



1.0

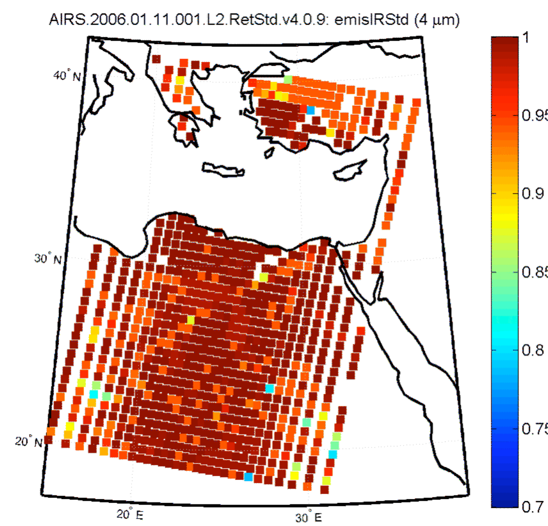
0.7

4 µm



1.0

0.7



1.0

0.7

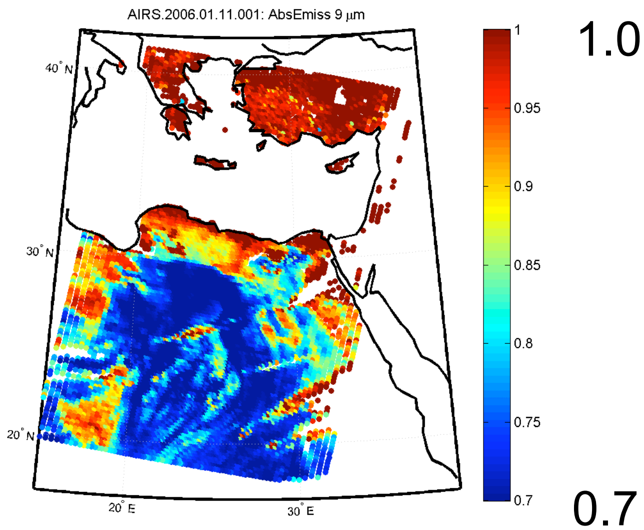
2006.01.11.001

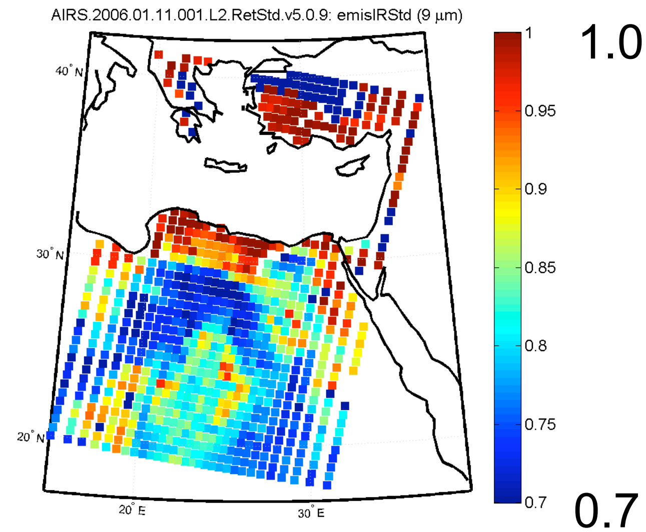
UW LSE Spectral Variance

AIRS STD Version 5.0.9

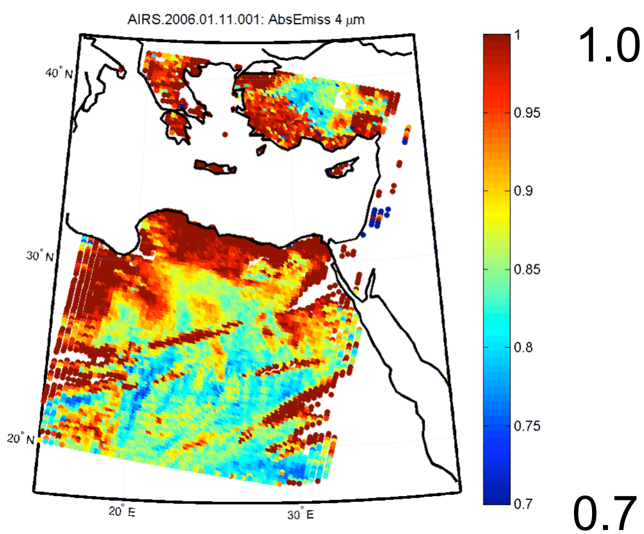
V5

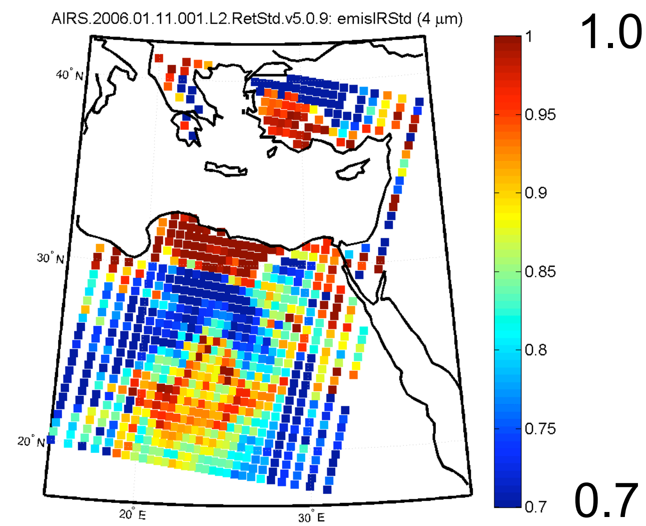
9 µm





4 µm





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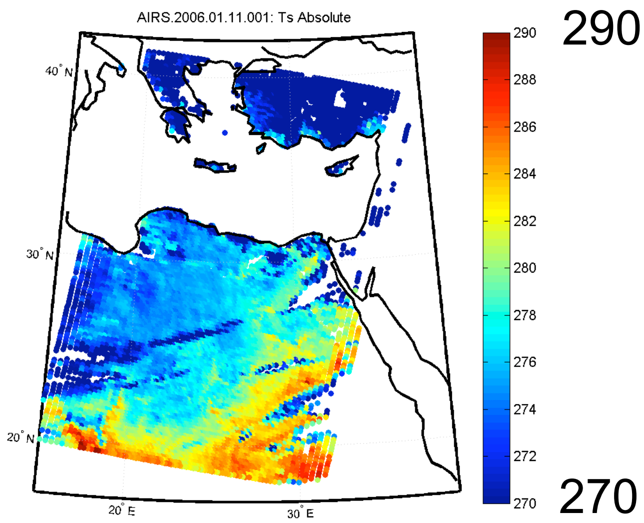
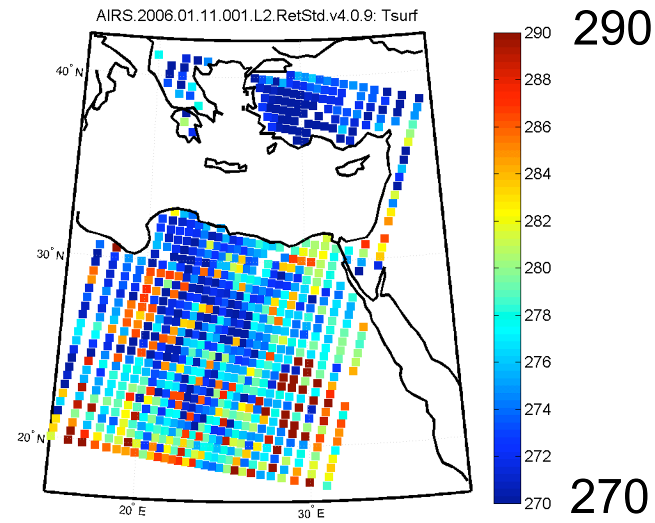
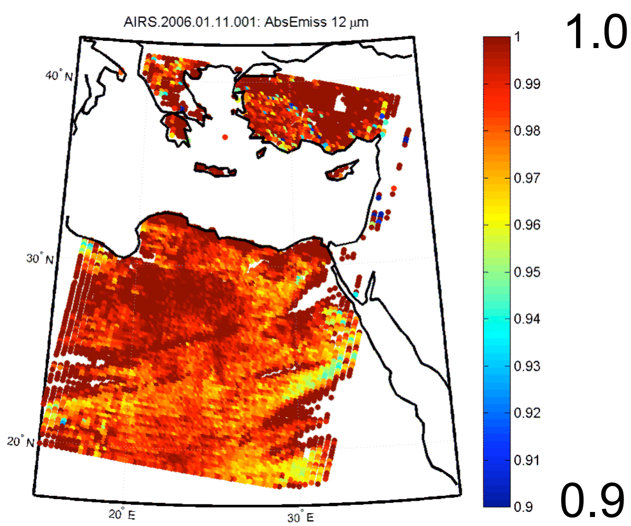
UW LSE Spectral Variance **AIRS STD Version 4.0.9** **V4**

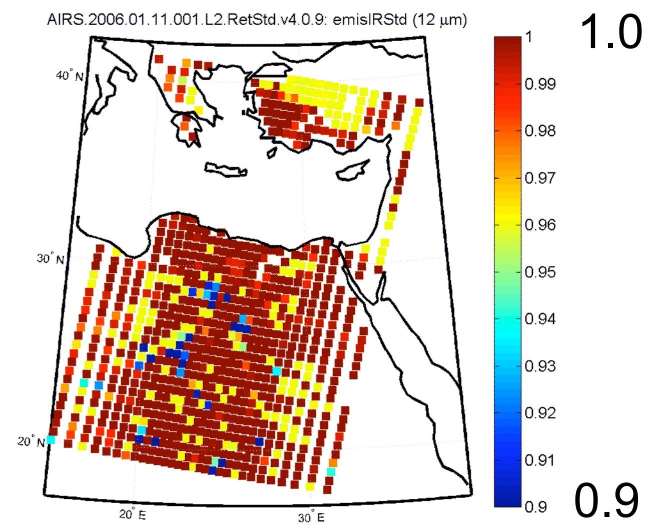
T surf





12 µm

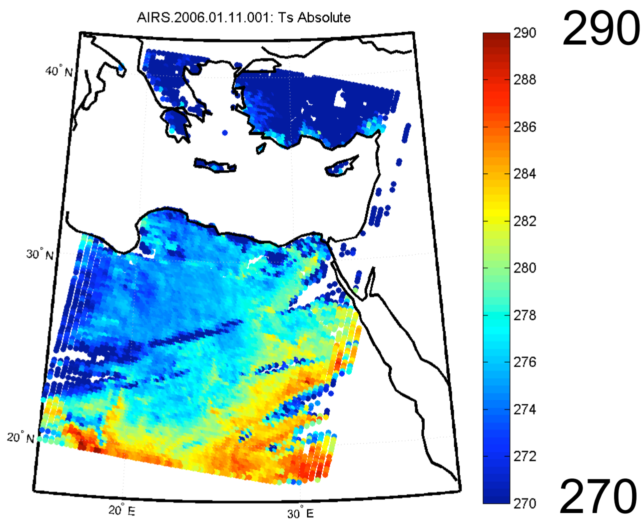


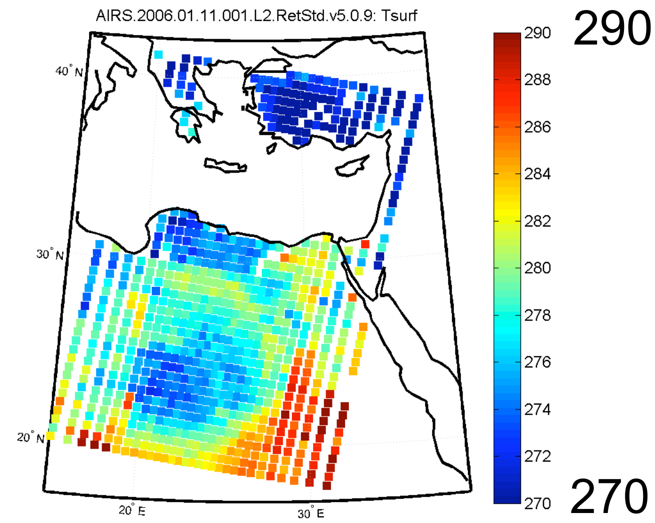


2006.01.11.001

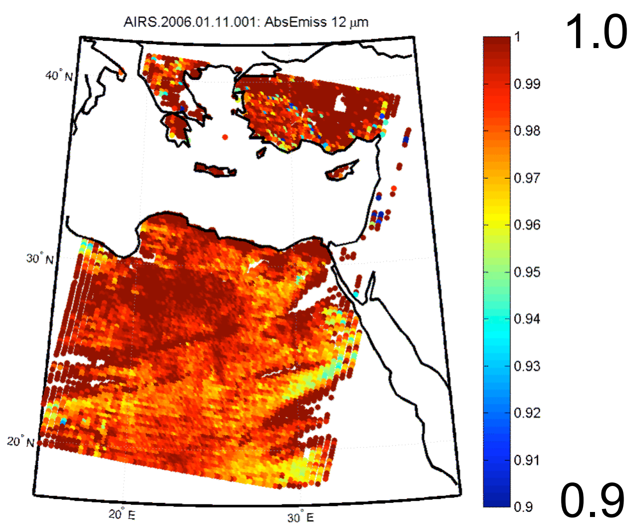
UW LSE Spectral Variance | **AIRS STD Version 5.0.9** | **V5**

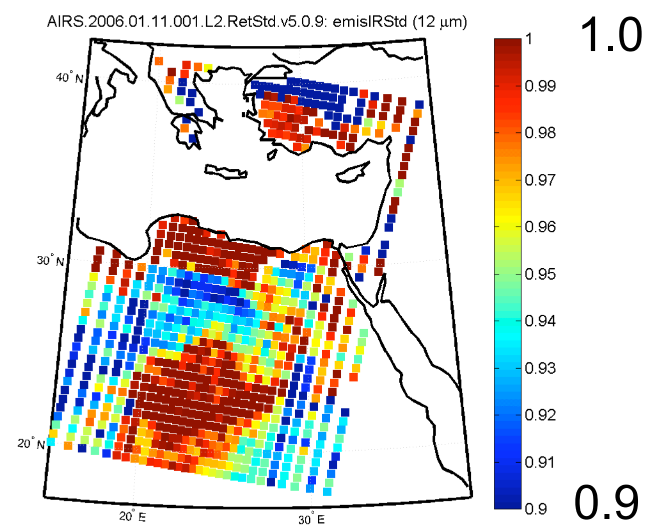
T surf





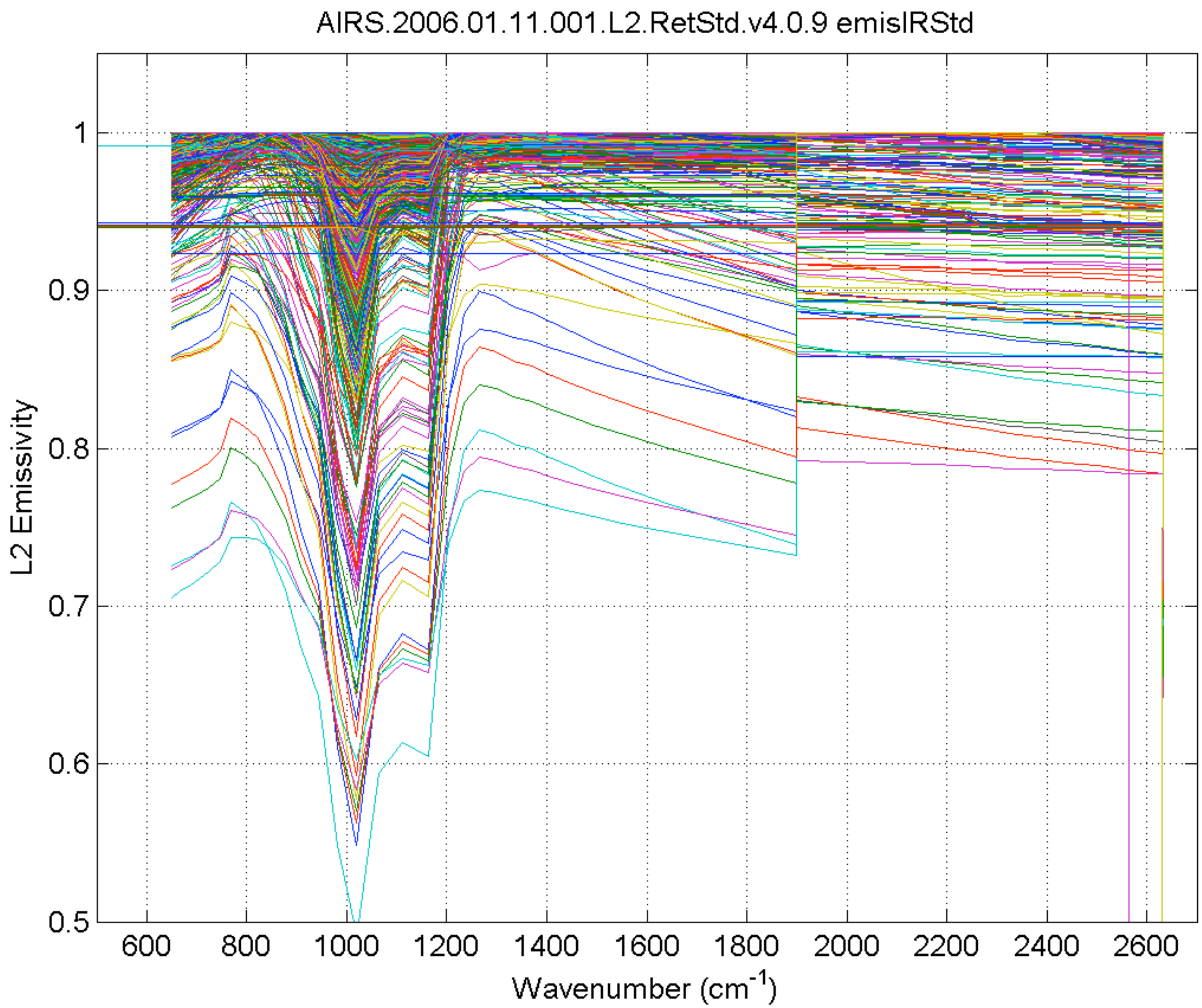
12 μm





2006.01.11.001

V4

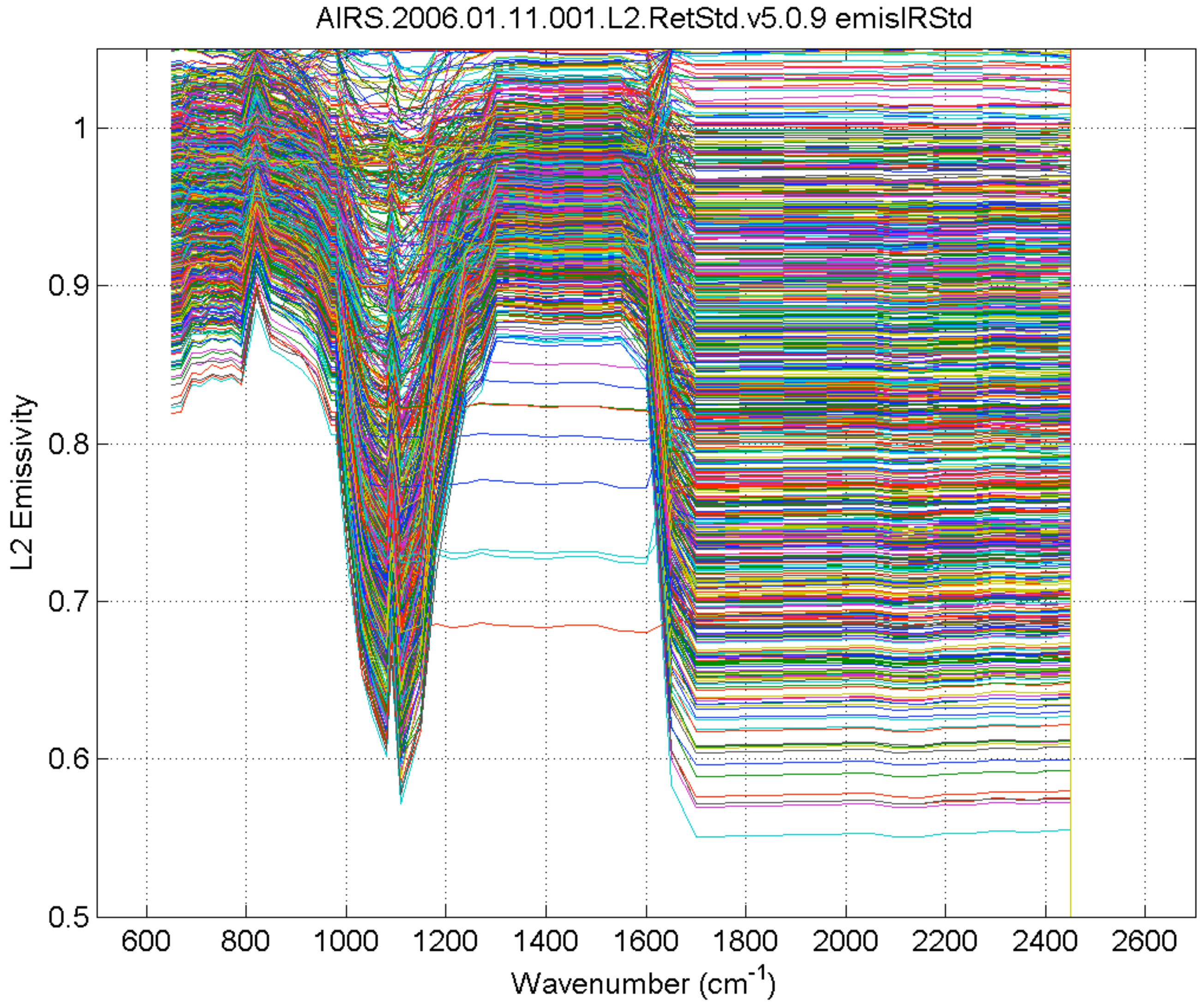


I don't know what to say about this!

2006.01.11.001

Uses Four Scaling Regions

V5

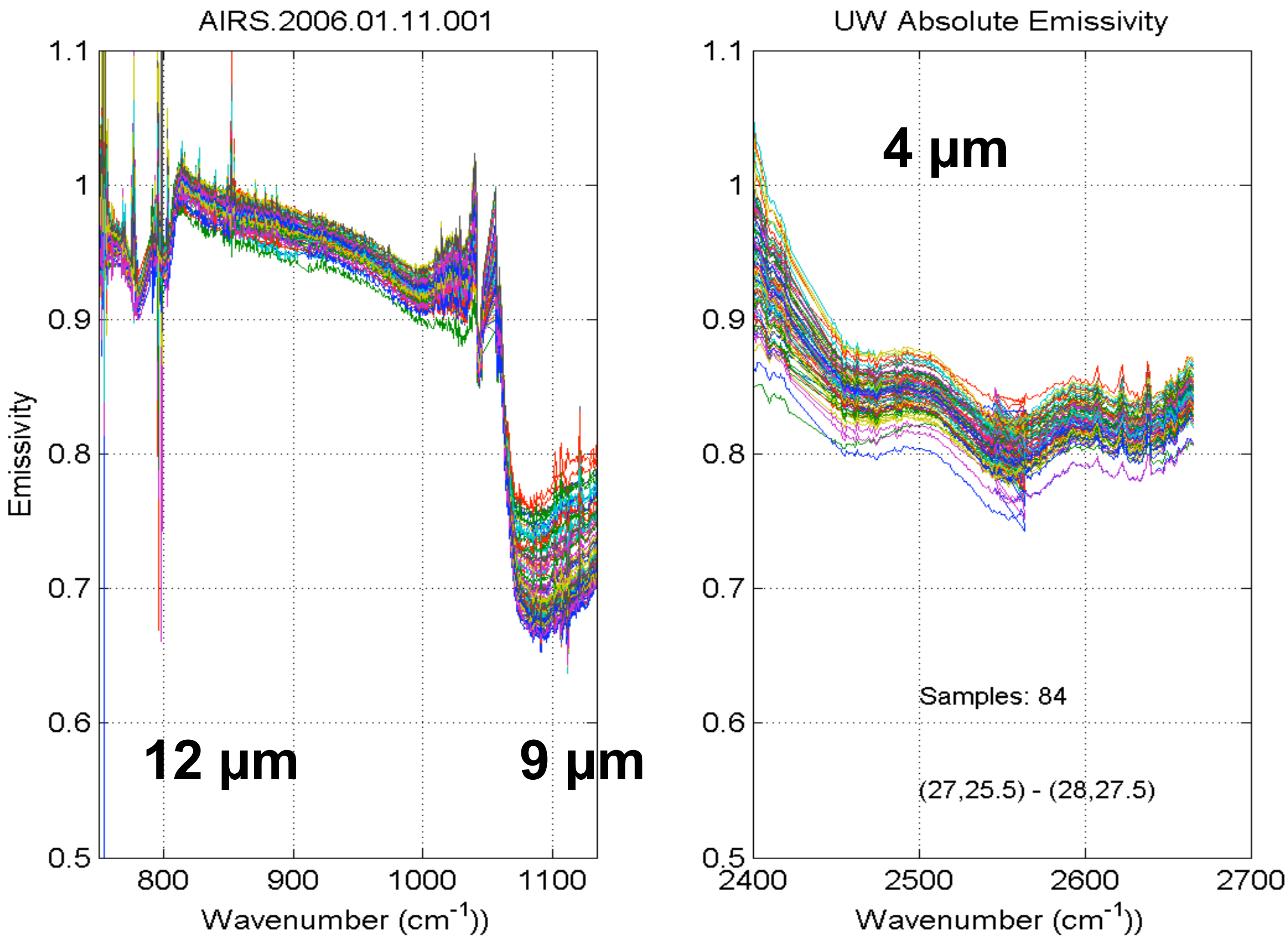


Shape coming from regression?

2006.01.11.001

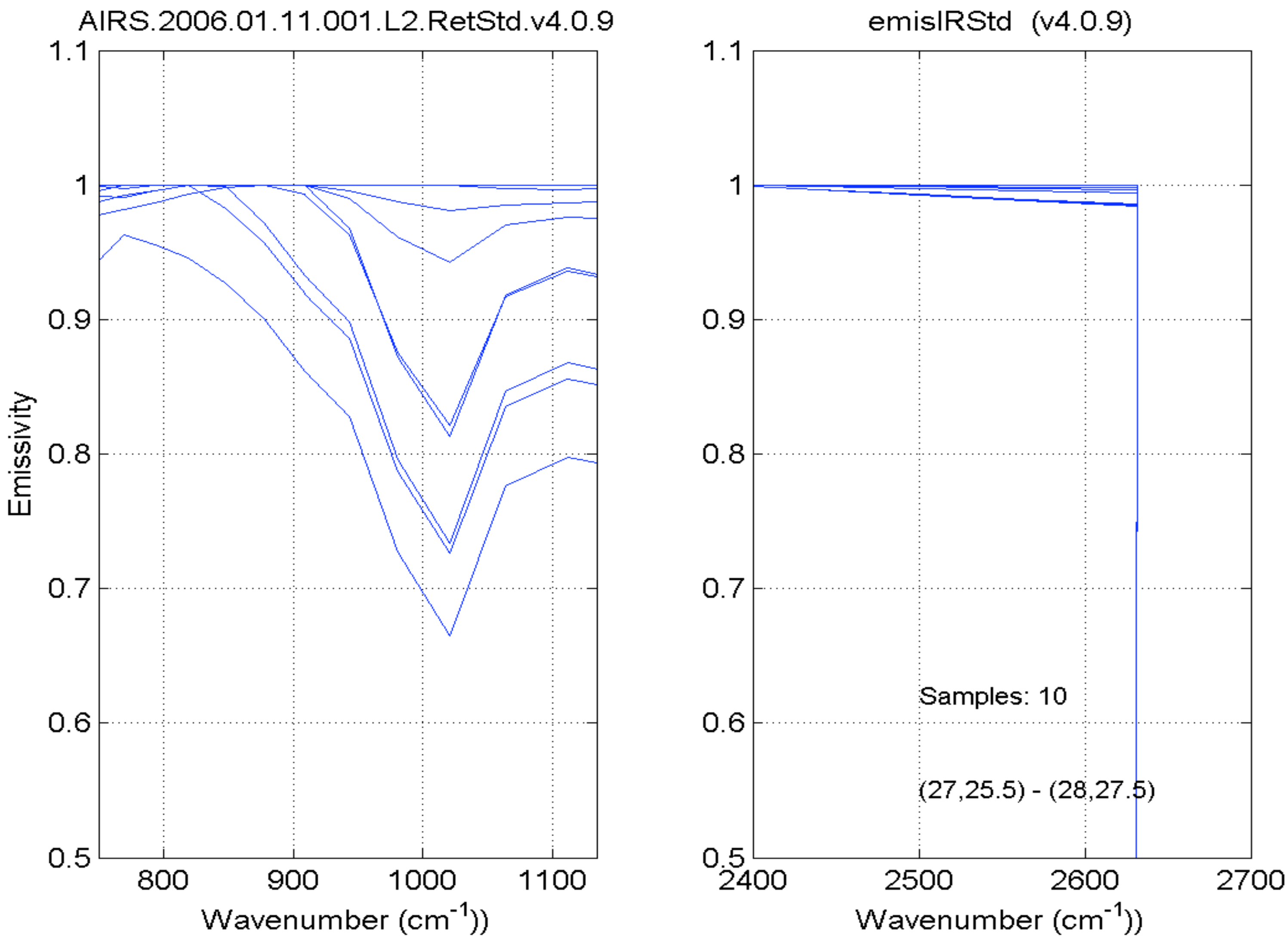
1x2 degree box over Sand Dunes (Egypt)

UW Val



1x2 degree box over Sand Dunes (Egypt)

V4



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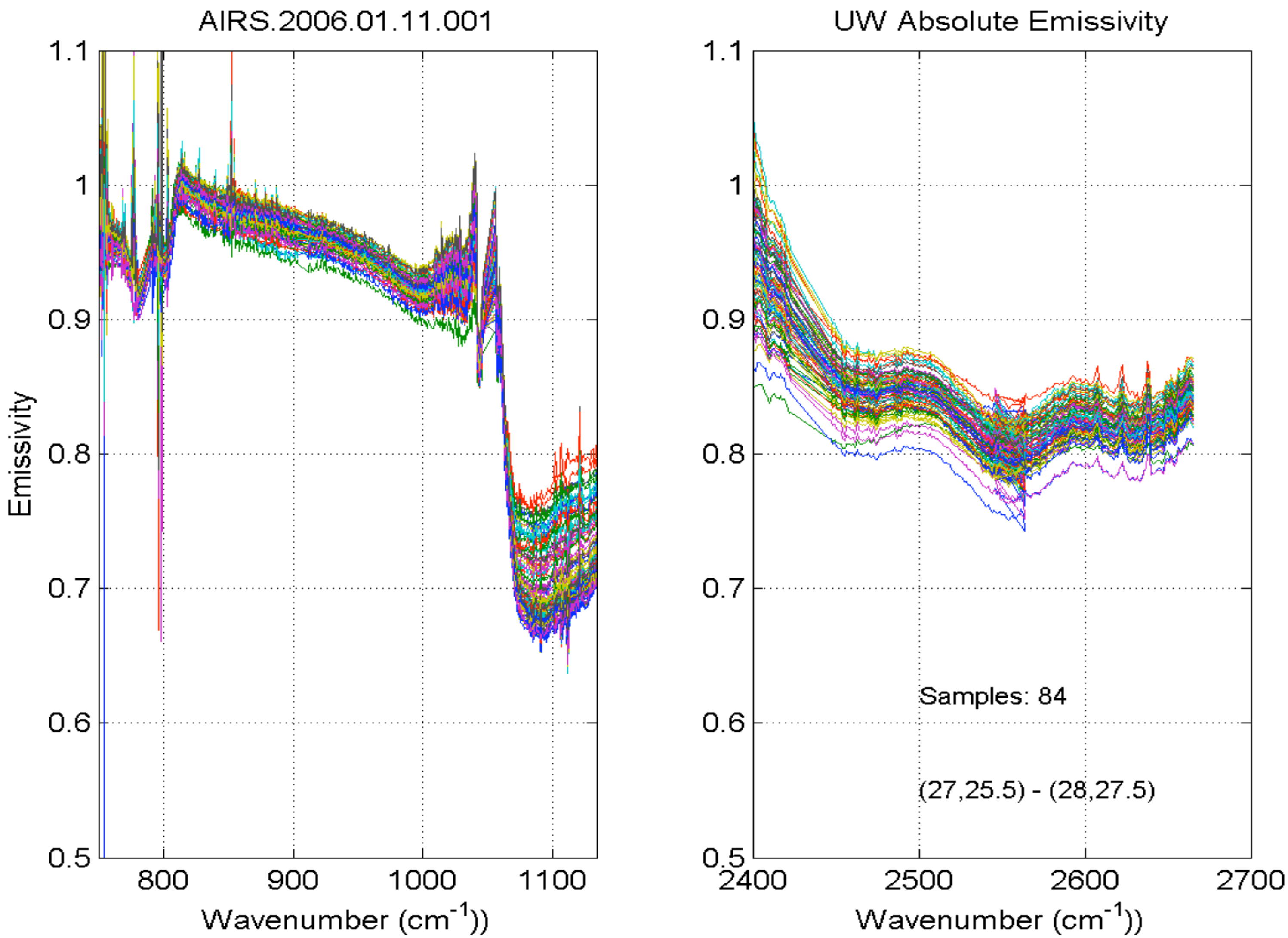
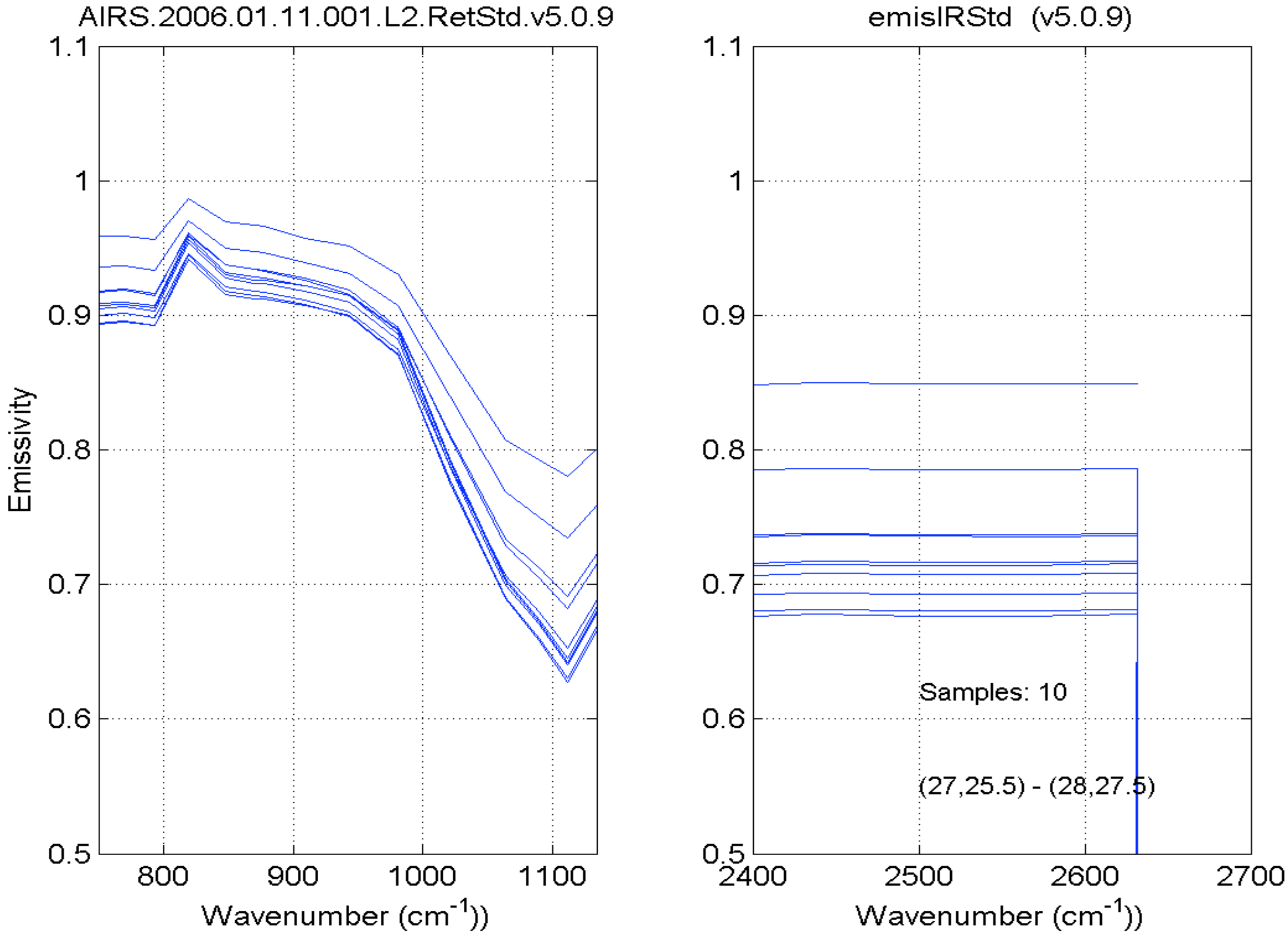
UW Val



1x2 degree box over Sand Dunes (Egypt)

V5



LEVEL 3 Product Comparison

AIRS PGE L3 version 5.0.7

- obtained 3 weeks ago but already superceded by a version that includes L2 QC relaxation of retrievals over the Sahara.

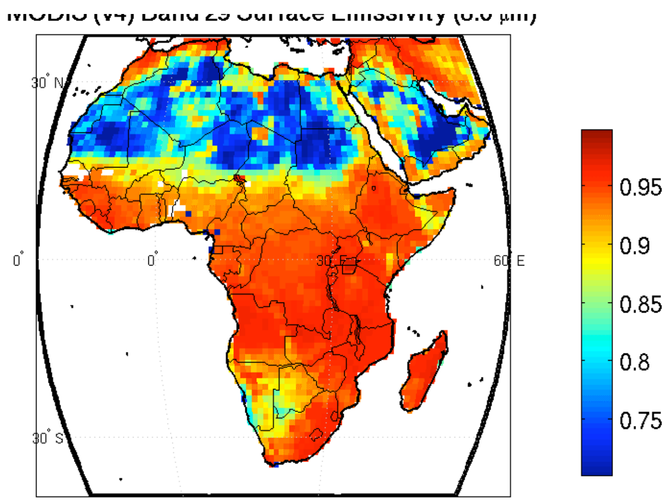
MODIS Land L3 collection 4

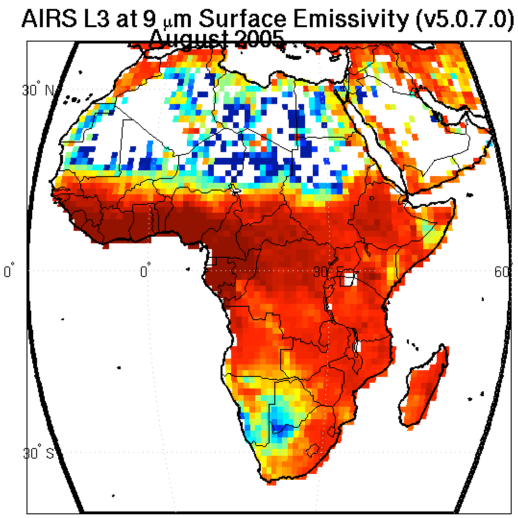
- UCSB Day/Night Algorithm (MYD11C)

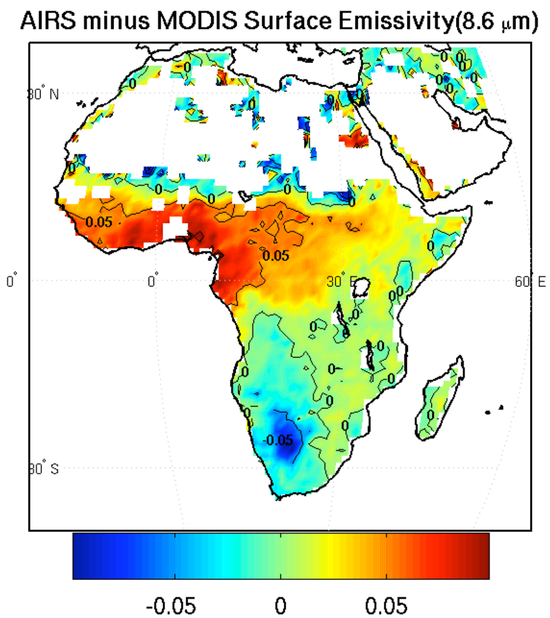
Only showing AUGUST 2005

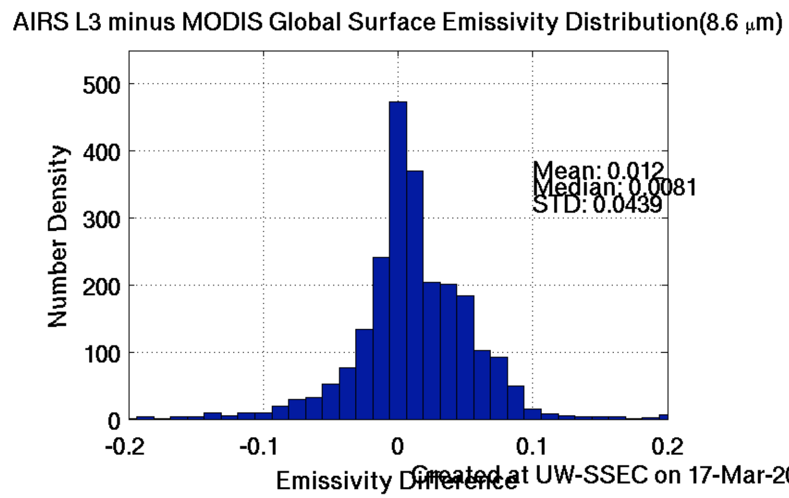
MODIS **AIRS**

9 μm





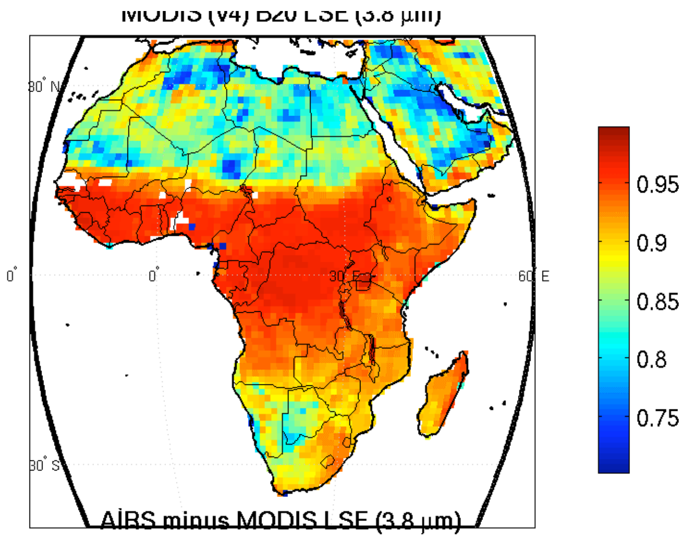




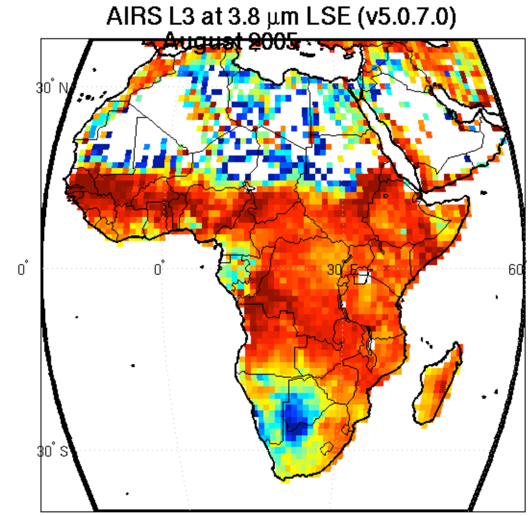
AIRS - MODIS **AIRS - MODIS**

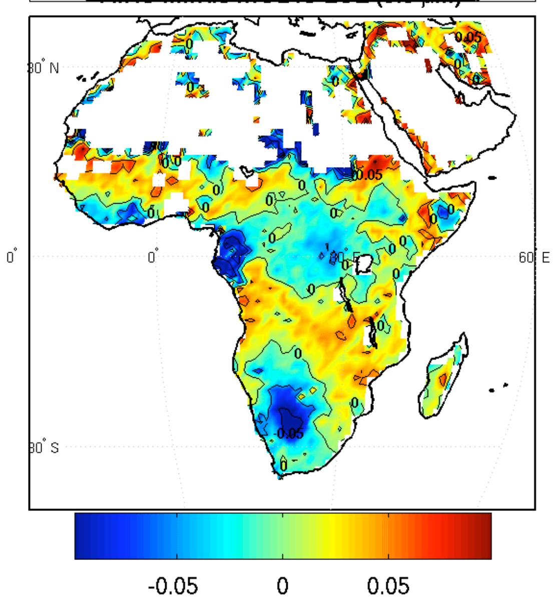
4 μm

MODIS

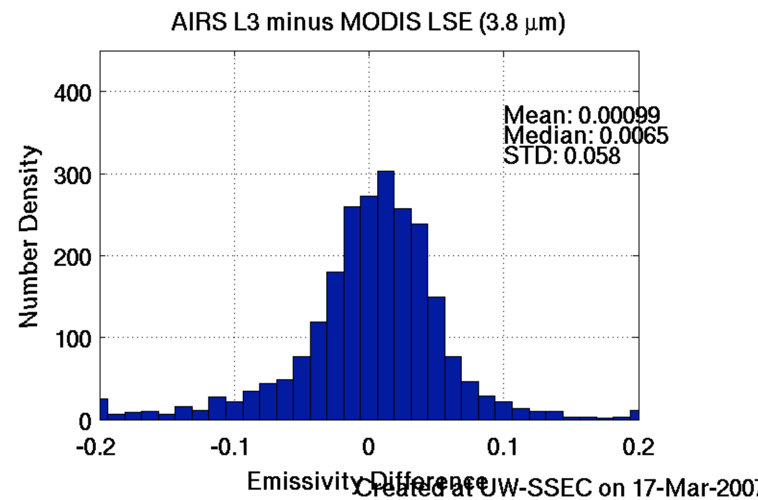


AIRS





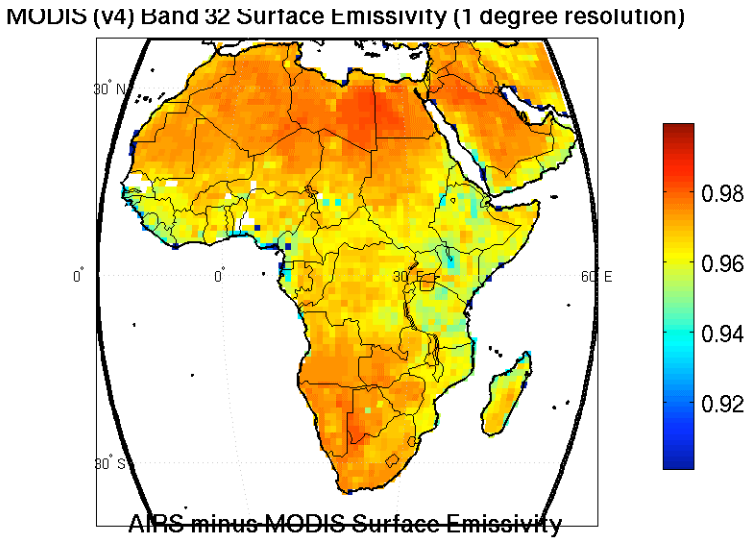
AIRS - MODIS



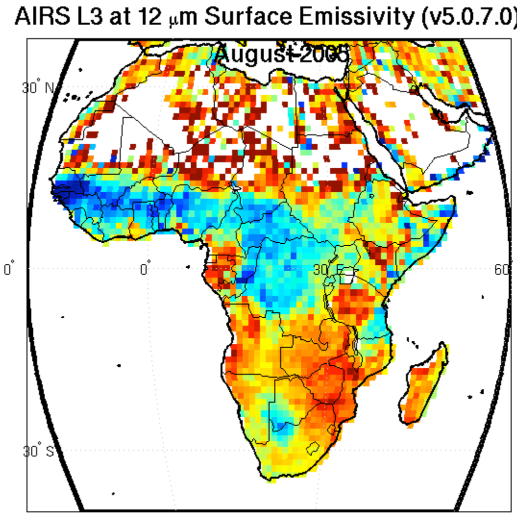
AIRS - MODIS

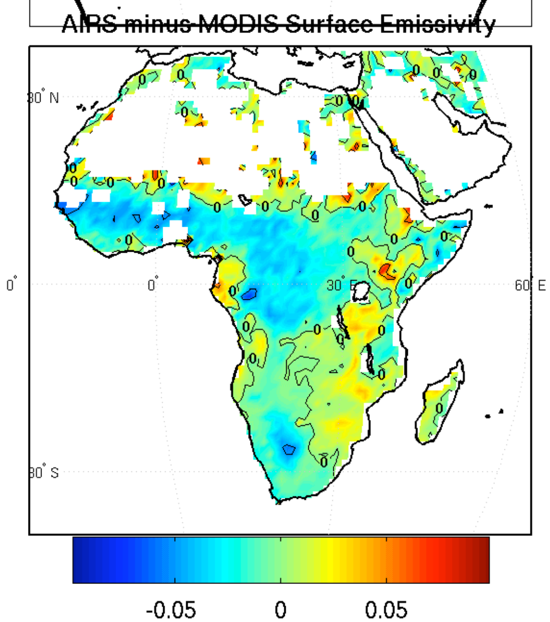
12 μm

MODIS

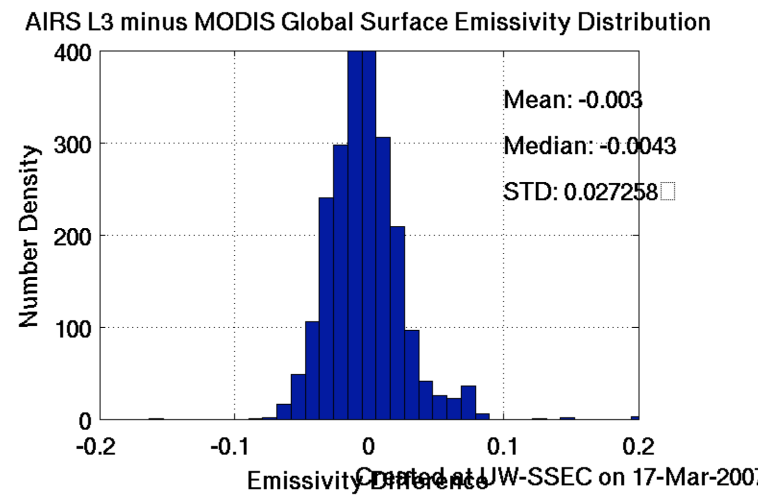


AIRS





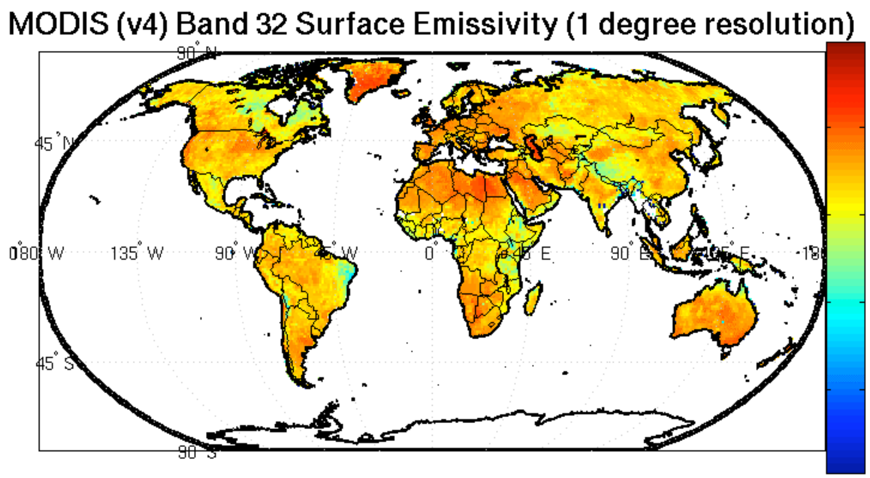
AIRS - MODIS

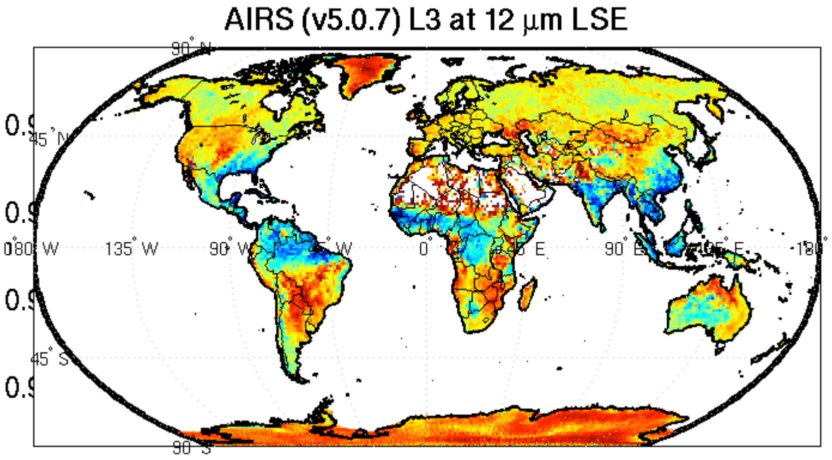


AIRS - MODIS

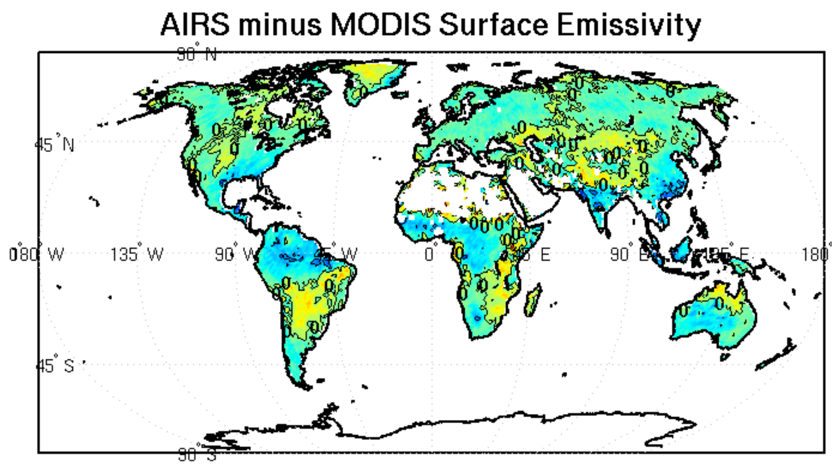
MODIS

AIRS

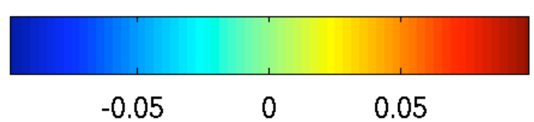


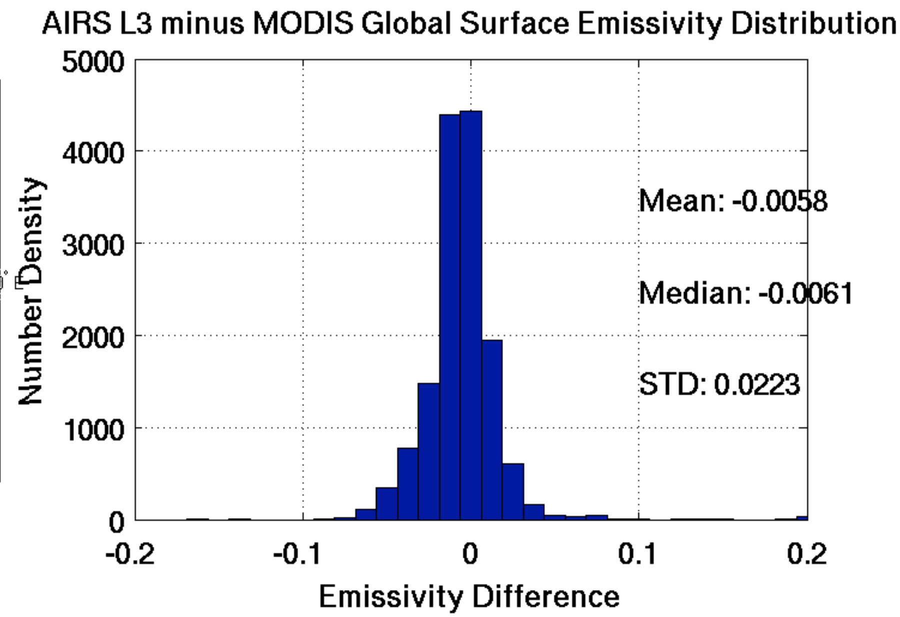


12 μm



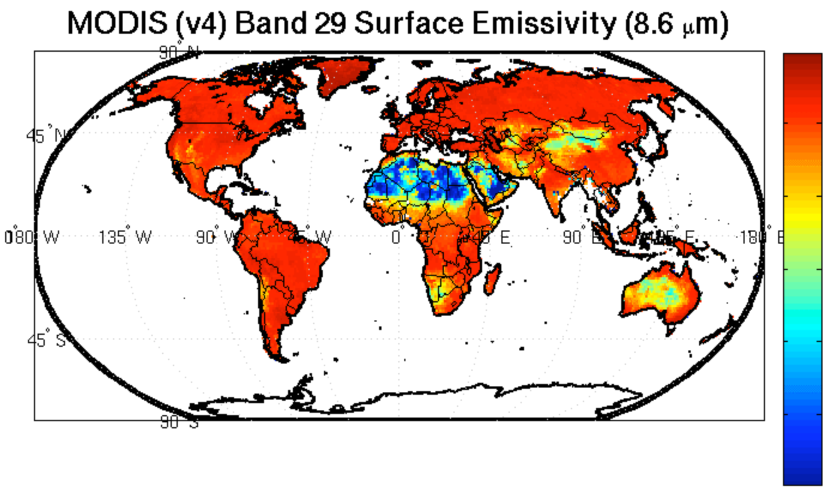
AIRS - MODIS

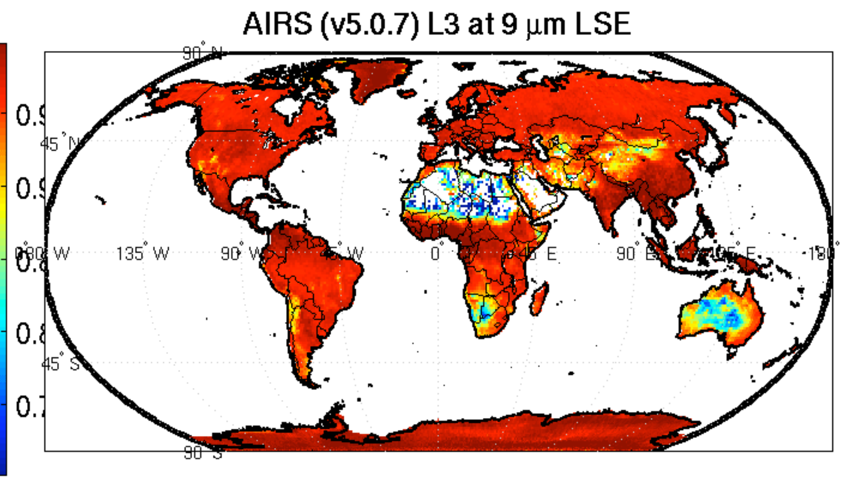




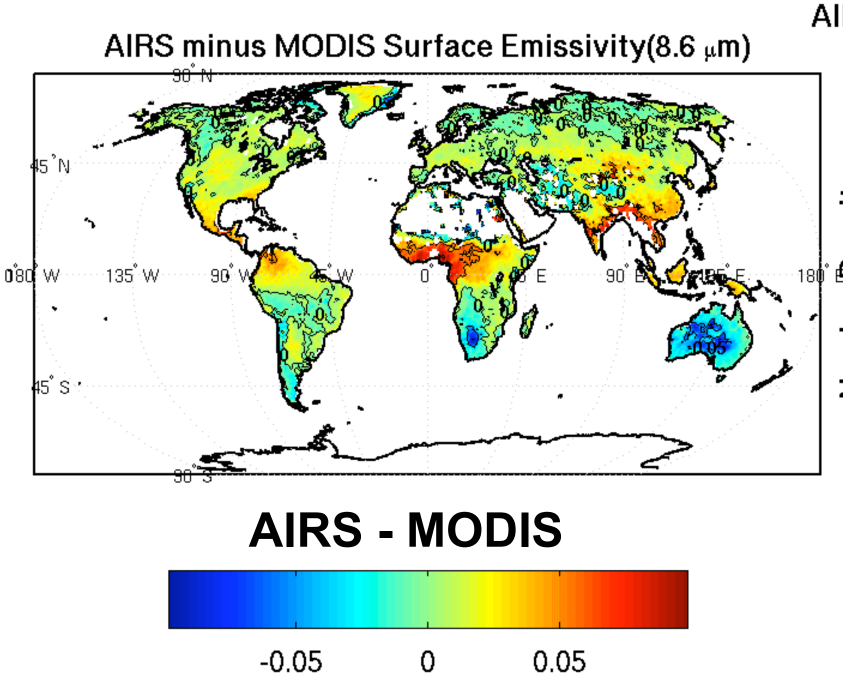
AIRS - MODIS

MODIS **AIRS**

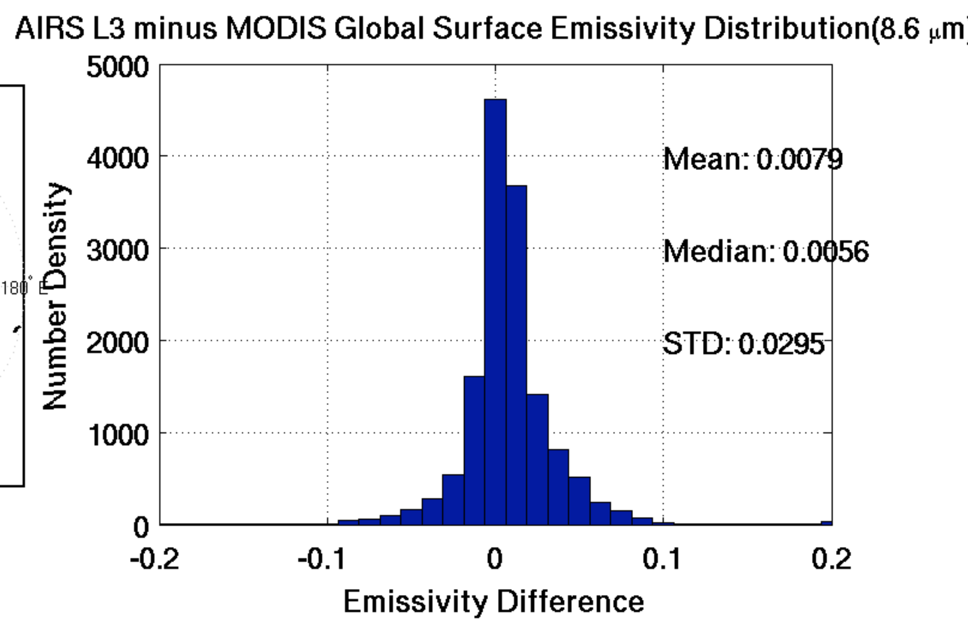




9 μm

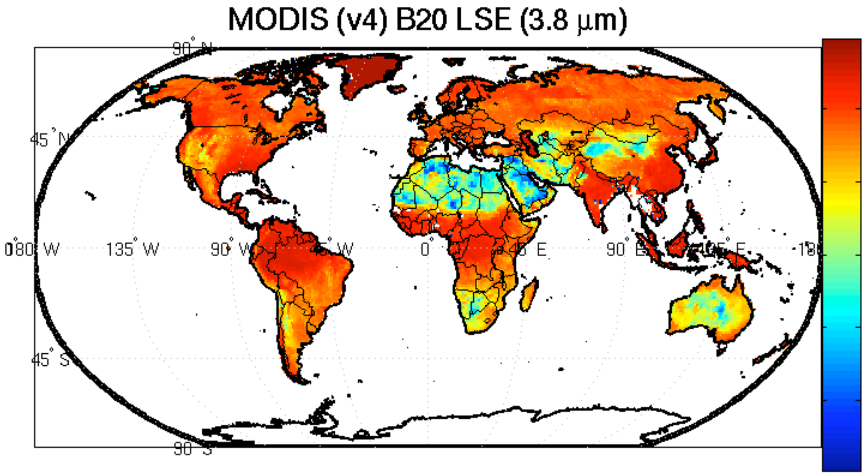


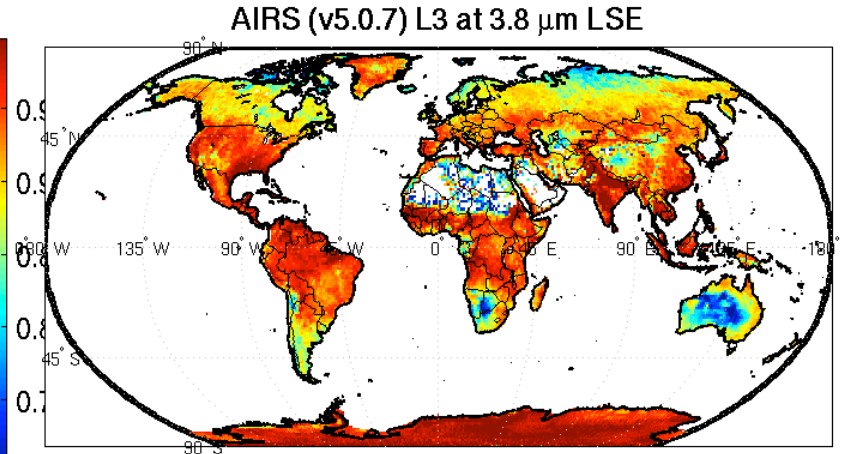
AIRS - MODIS



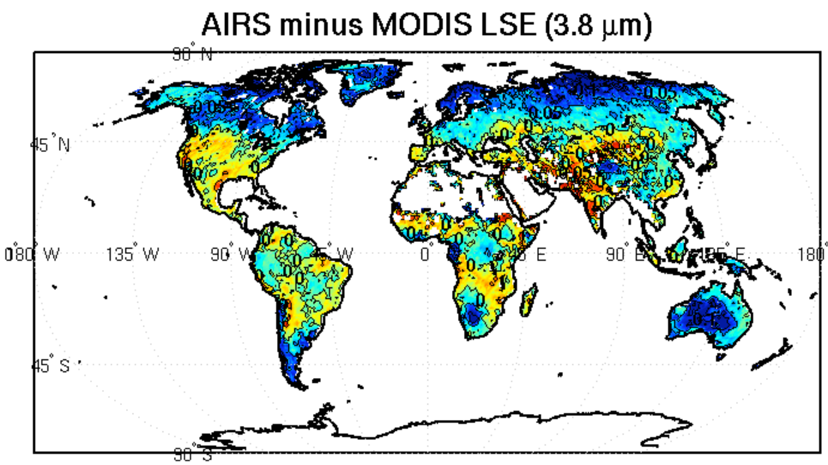
AIRS - MODIS

MODIS **AIRS**

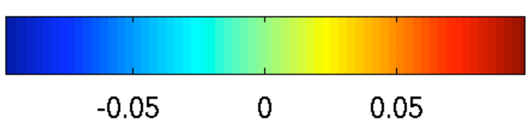


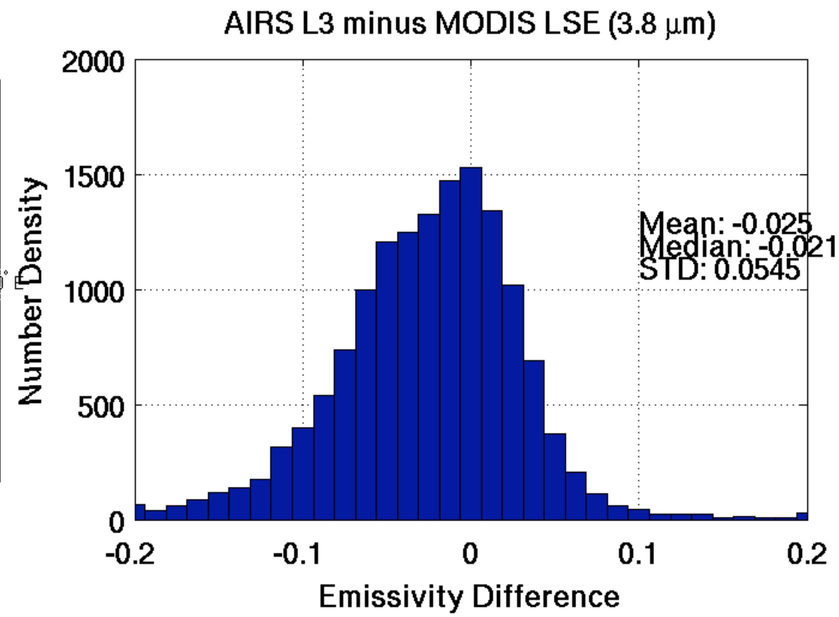


4 μm



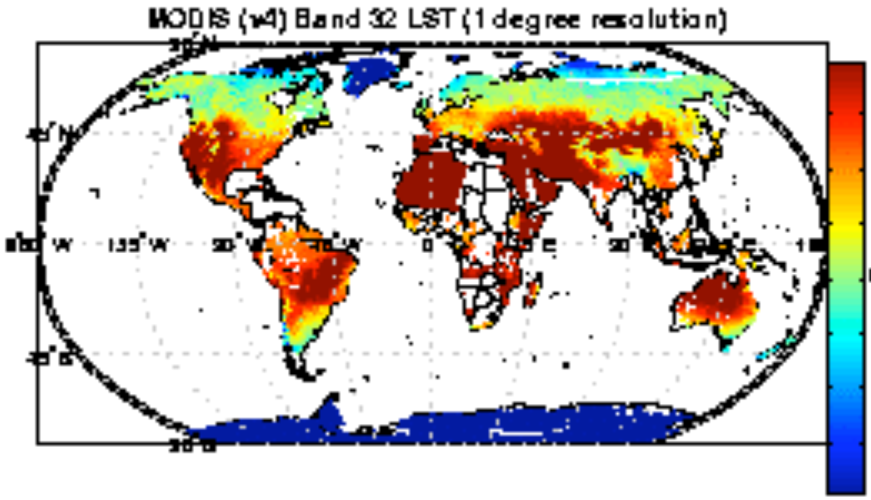
AIRS - MODIS



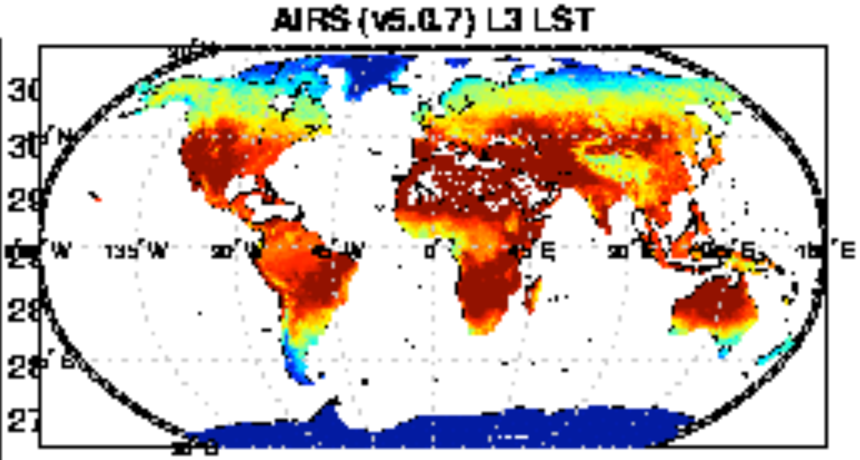


AIRS - MODIS

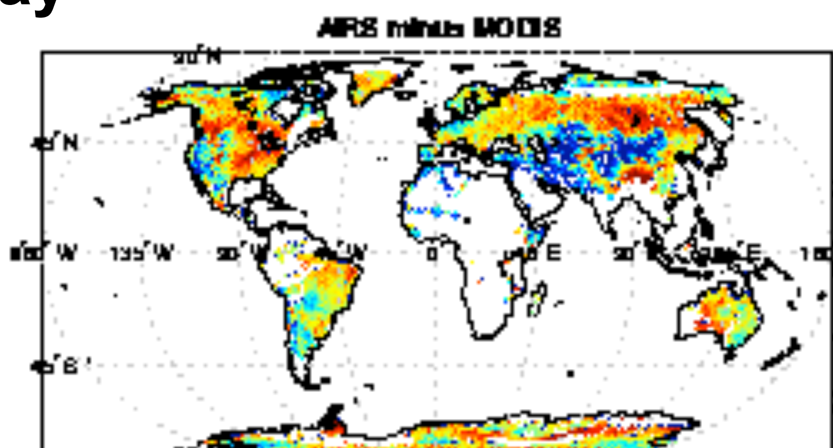
MODIS

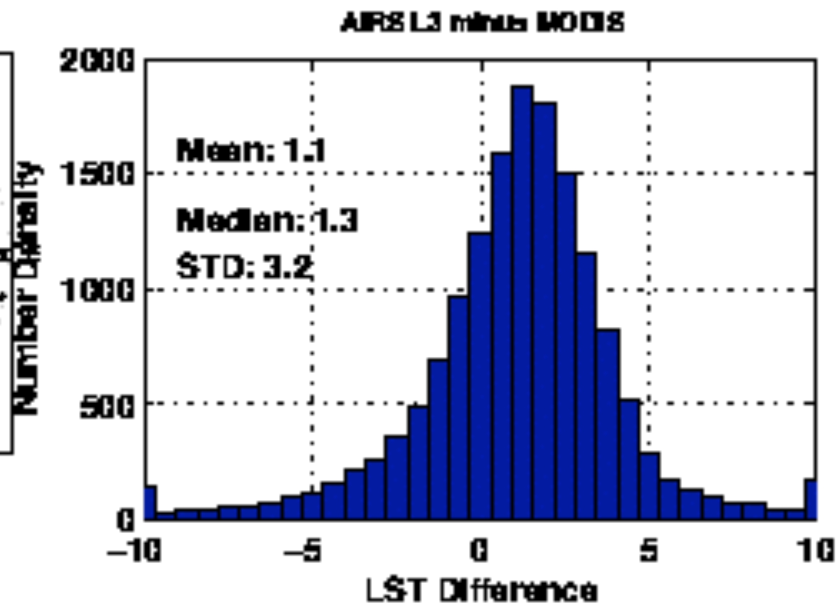


AIRS



Tskin Day





AIRS - MODIS

AIRS - MODIS

V4 to V5 Preliminary Conclusions

Comments related to AIRS PGE v5.0.9:

- **9 μm emissivity shows physical patterns (Is this a success of the initial regression by L. Zhou?)**
- **4 μm is too strongly correlated with 9 μm LSE (Should the regression training set be expanded?)**
- **12 μm is too strongly correlated with 9 μm LSE (Should this be constrained to physical values?)**
- **T skin is anti-correlated with 4 μm LSE (as well as 12 μm)**

V4 to V5 Conclusions (continued)

Suggest team algorithm adopt a method that constrains the emissivity to physically realistic values, e.g. 0.96 – 0.99 at 12 microns.

Some possible approaches for improvement:

(1) Use a mixing model of a constant and regression emissivity specrum in the final retrieval, or

(2) Retrieve the coefficients of PCA of laboratory emissivity spectra in physical retrieval with physical constraints, and/or

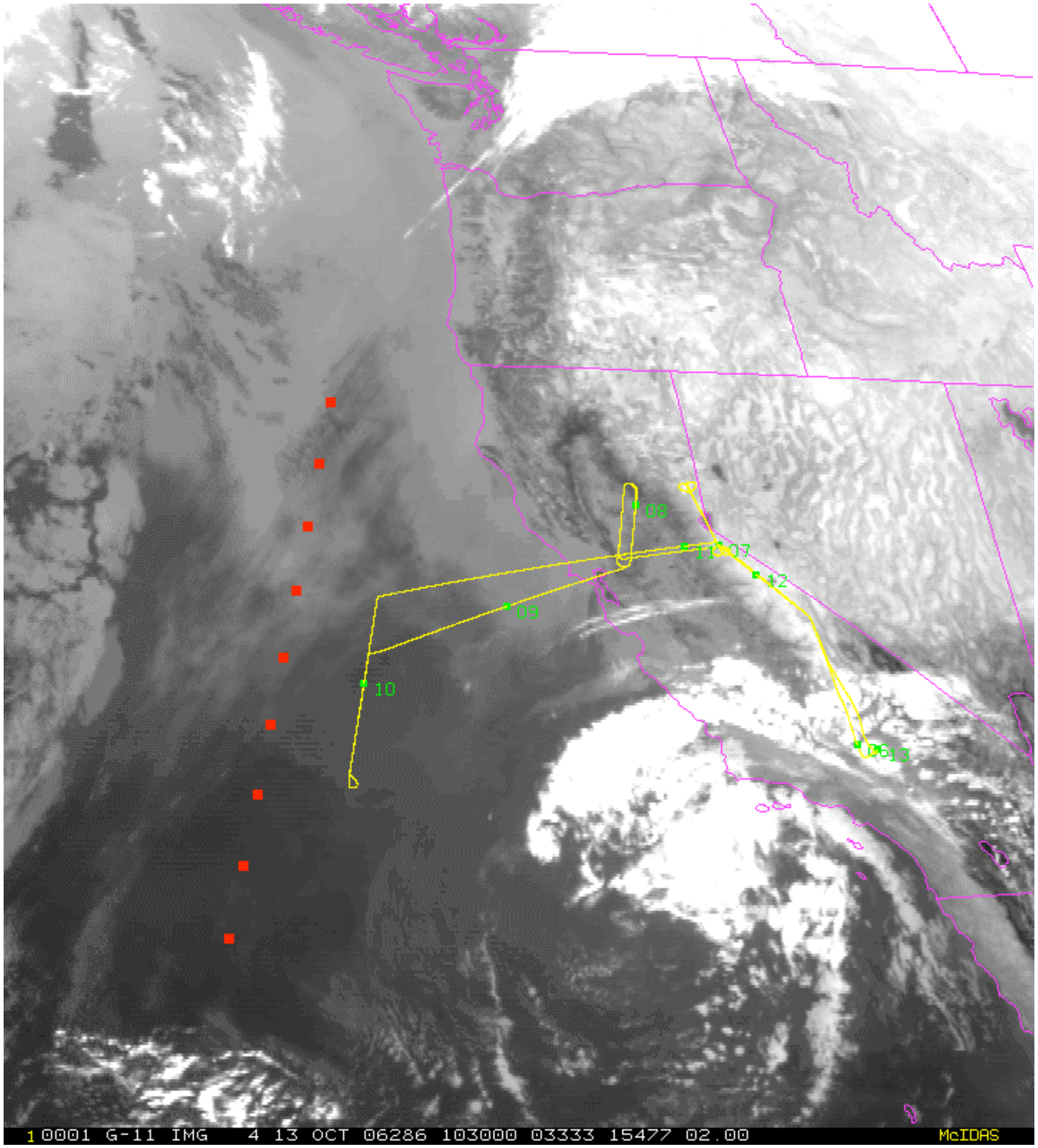
(3) Use a priori covariance map derived from either MODIS or AIRS LSE extended with lab spectra.

Backup Slides

Details

UMBC SARTA Version V106 (Fast Model for AIRS Channels)

- Atmosphere Emission only
- Atmosphere Transmission only
- Downwelling IR Transmitted to the TOA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Focus Day 16 November 2002: Egypt